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GRAIN AND FORAGE CROPS RESEARCH

of the

UNITED STATES DEPARTMENT OF AGRICULTURE
and related work of the
State Agricultural Experiment Stations

Section A

This progress report is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on USDA and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of USDA and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly USDA publications, Agricultural Research and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D.C.
December 15, 1967

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CURRENT SERIAL RECORDS



RESEARCH ADVISORY COMMITTEES

The following Research Advisory Committees were established pursuant to Title III of the Research and Marketing Act of 1946:

- | | |
|-----------------------------------|--------------------------------|
| 1. Farm Resources & Facilities | 8. Cotton |
| 2. Utilization | 9. Grain & Forage Crops |
| 3. Human Nutrition & Consumer Use | 10. Horticultural Crops |
| 4. Marketing | 11. Oilseed & Peanut Crops |
| 5. Agricultural Economics | 12. Plant Science & Entomology |
| 6. Forestry | 13. Sugar |
| 7. Animal & Animal Products | 14. Tobacco |

The source materials used by the advisory committees include organizational unit progress reports and subject matter progress reports. The latter contain information which was first reported in the organizational reports and has been assembled for use by commodity committees. The number prefixes shown below refer to advisory committees listed above.

ORGANIZATIONAL UNIT PROGRESS REPORTS

Agricultural Research Service (ARS)

- 1 - Agricultural Engineering
- 1 - Soil and Water Conservation
- 2 - Utilization -- Eastern
- 2 - Utilization -- Northern
- 2 - Utilization -- Southern
- 2 - Utilization -- Western
- 3 - Human Nutrition
- 3 - Consumer & Food Economics
- 4 - Market Quality
- 4 - Transportation & Facilities
- 7 - Animal Husbandry
- 7 - Animal Disease & Parasite
- 12 - Crops
- 12 - Entomology

Economic Research Service (ERS)

- 1, 5 - Economic Development
- 4, 5 - Marketing Economics
- 5 - Farm Production Economics
- 5 - Economic & Statistical Analysis
- 5 - Foreign Development & Trade
- 5 - Foreign Regional Analysis
- 5 - Natural Resource Economics
- 6 - Forest Service - Research (FS)
- 4, 5 - Farmer Cooperative Service (FCS)
- 4, 5 - Statistical Reporting Service (SRS)

SUBJECT MATTER PROGRESS REPORTS

- 6 - Forestry (other than Forest Service)
- 7 - Animal-Poultry & Products Research other than Husbandry, Disease and Parasite
- 8 - Cotton and Cottonseed
- 9 - Grain and Forage Crops
- 10 - Horticultural Crops
- 11 - Oilseed and Peanut Crops
- 13 - Sugar
- 14 - Tobacco

A copy of any of the reports may be requested from W. C. Dachtler, Executive Secretary, Grain and Forage Crops Research Advisory Committee, Research Program Development and Evaluation Staff, U.S. Department of Agriculture, Washington, D.C. 20250.

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This report on grain and forage crops research covers work directly related to the production, processing, distribution and consumption of grain, rice, feed, forage and seed and their products. It does not include extensive cross-commodity work, much of which is basic in character, which contributes to the solution of not only grain and forage crop problems but also to the problems of other commodities. Progress on cross-commodity work is found in the organizations' unit reports of the several divisions.

This report is organized by "Problem Areas" which are shown in the table of contents. For each area there is a statement of (1) the problem, (2) the USDA program, (3) State experiment station programs, (4) a summary of progress during the past year on USDA and cooperative work, and (5) a list of publications resulting from USDA and cooperative work.

Research on grain and forage crop problems is supported by (1) Federal funds appropriated to the research agencies of the USDA, (2) Federal and State funds appropriated to the State agricultural experiment stations, and (3) private funds for research carried on in private laboratories or for support of State station and USDA work.

Research by USDA

Farm research in the Agricultural Research Service comprises investigations on introduction, breeding and genetics, variety evaluation, culture, diseases, nematodes and weed control, insects, and crop handling and harvesting equipment and structures. This research is carried out in the Crops, Entomology, and Agricultural Engineering Research Divisions. It involves approximately 350 scientist man-years.

Nutrition, Consumer and Industrial Use research in the Agricultural Research Service pertains to composition and nutritive value, physiological availability of nutrients and their effects, new and improved methods of preparation, preservation and care in homes, eating establishments and institutions, new and improved food, feed, and industrial products and the processes related to grains, rice, and forages. It is carried out in the following research divisions: Northern, Southern, and Western Utilization; Human Nutrition; and Consumer and Food Economics. The work involves approximately 200 scientist man-years.

Marketing and Economic research is carried out in four services. Grain, rice, feed, forage, and seed research in the Agricultural Research Service deals with physical and biological aspects of assembly, packaging, transporting, and storing, and distribution. It is carried out by the Market Quality and Transportation and Facilities Research Divisions. Work in the Economic

Research Service deals with marketing costs, margins, and efficiency; market potential; supply and demand; and outlook and situation. Consumer preference studies and research to improve crop estimates are carried out by the Statistical Reporting Service. Research on cooperative marketing is conducted by the Farmer Cooperative Service. The grain and forage research in these Services involves approximately 70 scientist man-years.

Interrelationships Among Department, State and Private Research

A large part of the Department's research is cooperative with State experiment stations. Many Department employees are located at State stations and use laboratories and office space close to or furnished by the State. Cooperative work is jointly planned, frequently with representatives of the producers or industry affected participating. The nature of cooperation varies with each study. It is developed so as to fully utilize the personnel and other resources of the cooperators, which frequently includes resources contributed by the interested producers or industry. There is regular exchange of information between station and Department scientists to assure that the programs compliment each other and to eliminate unnecessary duplication.

Privately supported grain and forage crops research emphasizes the solution of specific production, processing, and marketing problems. Much of it utilizes the results of more basic work done by State stations and Department scientists. For example, private research is devoted to the synthesis and evaluation of chemicals as herbicides, fungicides, and insecticides, the development of new combinations of materials for use as fertilizers, product and process development, improvements in equipment for planting, cultivating, harvesting, handling, processing, drying and storing grains, forages and seeds. Private research in marketing and economics is largely concerned with studies of consumer preferences, market potential, promotion and market development.

The contributions of producers of grain and forage crops and of related industries to the work of State stations and the Department have been an important factor in the success of public research programs. Producers, processors, and distributors offer land, products, and facilities for the testing of equipment and practices used in the production and distribution of grain, rice, feed, forage, and seed and their products.

Examples of Recent Research Accomplishments

USDA and Cooperating Scientists

High Protein Oats. Protein content of 30 percent or more has been found among collections of Avena sterilis obtained from Israel and other Mediterranean countries. Comparable protein content for our highest cultivated oat

varieties is about 19-20 percent. In addition to high protein, unusually large groats (kernels) and outstanding resistance to crown rust and other major diseases have been found in A. sterilis. A. sterilis can be readily hybridized with cultivated oats. This new germ plasm should result in a breakthrough in the improvement of nutritive value, grain quality, disease resistance, and probable yield. Breeding programs have been initiated to accomplish this objective.

New Sorghum Germ Plasm. Seed from India, gained through P.L. 480 research, have been grown in nurseries in Puerto Rico to increase seed and to convert some of the sorghums to maturity types that can be suitably grown in the United States. These foreign types are being purified, increased, and stored at the National Seed Storage Laboratory, Fort Collins, Colorado. They have been made available to plant breeders and commercial seed producers. Some are being used to improve the economic characters of sorghum such as protein content and the modification of amino acid ratios.

Use of Insect Hormones to Control Alfalfa Weevil and Cereal Leaf Beetle.

Diapause has been successfully terminated in several adult insects including the alfalfa weevil and the cereal leaf beetle. Topical treatment of diapausing beetles with the potent synthetic juvenile-gonadotropic hormone 10,11-epoxyfarnesenic acid methyl ester induced previously diapausing beetles to begin feeding, mating, and reproducing within approximately a week after treatment. Since diapause is a protective mechanism which allows the insect to survive inclement periods of heat, cold, and drought, interruption of this protective state exposes the insect to a hostile environment at a time when it is unequipped for survival.

Wheat Flour Used as Paper Size by Industry in the Pacific Northwest. Wheat flour fractions modified by a process developed by Department scientists have been used as an additive by the paper industry in the Pacific Northwest. The process developed involves the enzymatic conversion of the flour to a desirable form, is simple to operate, and is readily applicable in existing paper mills. The process works with various types of flours, but best results are obtained with flour from soft wheat. Wheat produced in the Pacific Northwest is practically all soft wheat. The paper industry is also concentrated in this region. Thus, a market is available for industrial grade, regionally produced flour that can compete with other commercial products currently used as paper size, practically all of which must be imported or obtained from other regions of the United States. At least three industrial companies have used the flour on a plant scale.

New Industrial Starch Developed. Through the cooperative effort of Department scientists, corn breeders, university personnel, and industry, corn starches containing various amounts of amylose are now commercially available. Two starches are now marketed, namely, one containing 50-60 percent amylose and one containing about 70 percent amylose. The starch in regular yellow dent corn contains only about 27 percent amylose. Control of the amylose content provides new and diverse markets. In general, the film-forming properties of starch improve in proportion to its amylose content. Growing industrial markets for the new starches are found in the manufacture of glass fibers and paper products. Other potential uses include edible coating for foods. Three large industrial corn-milling companies are now processors of the corn grown under contract by farmers.

New Food-Protein Concentrates from Wheat now Available. Major flour milling companies are producing a new type of protein-rich concentrate for use in foods. Based on Department research, the new products are derived from byproduct fractions normally disposed of in animal feeds at low returns. In the form of finely powdered materials they are being offered for use in such products as baked goods, ready-to-eat breakfast cereals, and high-protein products for food aid programs overseas. Initial government procurements are being made of two products. One will contain the new concentrate in pre-cooked form as part of a blend of ingredients comprising a beverage for youngsters. The other is a protein-enriched flour for Asiatic baked products. The new concentrates are light amber in color and mild in flavor. They contain 20 to 35% protein which has at least 4% of the scarce amino acid lysine. More than a million tons of food-grade concentrate can be produced per year, and nearly as much of a lower quality product will be available for use as an upgraded poultry-feed ingredient.

More Efficient Rice Drying. Department scientists have helped the California rice drying industry handle nearly twice the drying load of a decade ago. The practice of harvesting rice at higher moisture contents than before accounts for much of this increase in drying load. Utilization research showed that increasing the air temperatures and shortening the tempering periods between multiple passes in the columnar drier could speed up the process with no loss of milling quality. Recently, Department scientists developed more accurate, simplified control methods. In 1966 they tested the methods under field conditions in cooperation with industry and the California State Agricultural Extension Service and Experiment Station. By increasing air temperature, drying efficiency was increased, boosting the capacity of existing driers almost 40%. The majority of California rice driers will use the improved procedures for the 1967 harvest season. Annual savings in drying costs and the increase in milling yield that are now possible reach nearly \$2 million per year.

New Process Leads to First Commercially Available Supergrade Alfalfa.

Cooperative work of Department scientists with Nebraska State Department of Agriculture and industry led to development of a process for separating the fibrous fraction from the high-protein fraction of alfalfa after dehydration. The process is based on a differential grinding step whereby the leaf is reduced in particle size while the tougher stem is left in relatively large particles. This step is followed by screening or air classification to produce a high-xanthophyll, high-protein product for poultry rations and a high-fiber fraction for ruminants. Based on this work, the first 25%-protein alfalfa product ever to be made commercially available has recently been announced by a major alfalfa dehydrating company. Many other firms are expected to follow suit during the coming year. The two standard grades of alfalfa meal contain at least 17% and 20% protein. The new product is richer in all nutrients measured than the standard grades and is better suited for poultry because of its greatly reduced fiber content.

A Two-Fan Crossflow Aeration System for Stored Grain. A new 2-fan crossflow aeration system developed for upright grain storages supplies airflow rates 5 to 10 times higher than conventional systems having the same horsepower. At least 25 percent of the reported 20,000 country and terminal elevators should be able to use this system in one or more of their storage bins to reduce marketing costs. Interest in this system is evidenced by the 3,000 requests received since a report was published three months ago. A saving of but 1/2 to 1 cent per bushel in operating costs and spoilage losses of corn and wheat now requiring drying would amount to an annual saving of 10 to 20 million dollars to producers and consumers.

State Agricultural Experiment Stations

Short-Statured Wheat Varieties. The variety, Blueboy, was released in North Carolina and the variety, Sturdy, in Texas to meet the need for varieties that are more resistant to lodging and capable of responding to higher levels of nitrogen fertilization. Blueboy is a soft red winter wheat variety and Sturdy is a hard red winter wheat variety. Both have been selected for adaptation and resistance to diseases in the States for which they are released.

Parasite Controls Rhodesgrass Scale in South Texas. Texas Agricultural Experiment Station entomologists have known the effectiveness of using the wingless wasp, Neodusmetia sangwani, to parasitize Rhodesgrass scale for some time. Now with the aid of high speed distribution, the concept could easily be employed to treat the entire area infested with scale. Large areas have been seeded with grass sprigs infested with scale, which in turn, are parasitized by the wasp. The grass sprigs are dispersed by dropping them in frozen food cartons from low-flying aircraft as in the screw-worm

eradication program. The parasites emerge from the grass sprigs and attack the scale in the area where they are dropped. They spread over large areas. Experimental drops have shown remarkable reduction in scale populations and substantial increases in forage yields. The research is supported by a grant from the Entomology Research Division.

Thin Flaking of Corn for Cattle Feed. The proven superiority of flaked corn over other conventional methods of processing feed grains has led Colorado station workers to study the degree of thinness or thickness most suitable for cattle feeders. Comparison of "thin" flakes (1/32-inch) with "thick" flakes (1/12-inch) in heifer feeding trials of 163-day duration demonstrated a greater feed efficiency and a cheaper cost of gain favoring "thin" flakes. Average daily gain was 2.82 for thin flakes contrasted with 2.70 pounds for thick flakes, whereas mash-fed animals showed gains of only 2.65 on control diets with finely ground corn passing a 1/4-inch screen. At a selling price of \$25 per cwt. final weight and with lowered feed costs plus increased returns owing to greater gains, a total advantage of \$8.13 per head accrued for animals fed thin flakes. These significant savings resulted from adjusting the tightness setting of the rolls used for flattening steamed corn to produce flakes having a 1/32-inch thickness after drying to 12 percent moisture.

Nutritive Value of Sorghum Grains. Differences in the protein content of sorghum grains may affect the nutritive value of poultry diets and thus may be regarded as an important quality factor in feed formulation. Although the amino acid composition of the sorghum proteins was similar in sorghum grain samples containing 8, 10, and 12 percent protein, research workers at Kansas State showed that sorghum grains of high protein content produced significantly more gain than low protein grain when substituted for corn in rations containing a constant level of soybean meal. Calculated limiting amino acids in the diets were methionine and glycine, with arginine and lysine next most limiting. Chick performance was not affected by protein levels when the grain was formulated into diets of equal protein.

Protein Alteration in Flour Damaged by Milling. Overgrinding of flour affects flour quality. North Dakota scientists studied protein alteration in flour milled with varying degrees of severity by means of nonprotein nitrogen (NPN) determinations, specific color reactions, Sephadex column chromatography, gel electrophoresis, and sulfhydryl group analysis. The proteins of the water-soluble fraction were given special attention. The possibility of protein denaturation in highly damaged flour was indicated by a decrease in the total flour nitrogen contained in the water-soluble fraction. An increase in NPN in the water-solubles was observed as severity of milling increased. Two color reactions for the measurement of amino groups supported the NPN units. In addition, the water-soluble proteins produced two main peaks when separated on a Sephadex 7-50 column. Average

values for several column determinations indicated a slight increase in the lower-molecular-weight protein content of the damaged flour. These data indicate an alternation of protein structure.

Processing Long-Grain Rice. Texas Station researchers have investigated the effects of variety, degree of parboiling, pH, calcium lactate addition and blanching on long-grain rice canned in a liquid medium. Definite varietal effects were found. A pH of 6.5 was near optimum. Severity of parboiling was directly related to texture and appearance. Calcium lactate additions did not improve quality.

Rust Resistant Large Kerneled Durum. The North Dakota Agricultural Experiment Station and the Crops Research Division, ARS - USDA, released a rust resistant durum wheat called Leeds. Leeds is the first wheat with improved rust resistance, kernel weight and test weight released through this cooperative effort. Leeds has good milling and macaroni processing qualities; and high wheat and semolina protein. This variety should prove satisfactory in domestic as well as in foreign markets.

I. FARM RESEARCH

BARLEY BREEDING AND GENETICS, DISEASES, QUALITY, AND PHYSIOLOGY Crops Research Division, ARS

Problem. The yield and quality of barley fluctuates with changes in certain factors such as climate, soil, diseases, lodging, winterkilling, shattering, drought, and insect damage. Commercial processing procedures for the production of malt and malt liquors are undergoing changes at the present time, and this raises the question of the suitability of presently used varieties for these purposes. The constant replacement of new varieties for older ones and the changes in processing procedures by industry for producing malt and malt liquors call for an even greater awareness in the suitability of the new varieties for industrial use. This problem will be increased when hybrids make their appearance. Barley diseases continue to cause great losses in barley. They lower the quality of the grain and restrict the area where high quality barleys can be grown. Additional work needs to be done to measure the amount of hybrid vigor in barley, to determine factors that will increase cross-pollinations, to learn the relation of mitochondria to heterosis, to find other or alternate systems for producing hybrid seed, to study the effect of hybrid vigor on quality, disease, and insect resistance, and on field managerial procedures geared to reduce the cost of seed. Increased efforts on basic research are needed in genetics, cytology, pathology, physiology, and breeding methods to provide information to strengthen the breeding programs, the work on quality, and to provide a fuller understanding of the nature of winterhardiness, aluminum toxicity, host-pathogen relationships, and the relation of molecular structure to gene action.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-range basic and applied program conducted by geneticists, pathologists, cytologists, physiologists, chemists, and agronomists, and related to the improvement of barley. Barley research investigations are conducted at Beltsville, Md., and in cooperation with the following State Agricultural Experiment Stations: Arizona, Idaho, California, Michigan, Minnesota, Montana, North Carolina, North Dakota, South Dakota, and Wisconsin. A Federal National Barley and Malt Laboratory is located at Madison, Wis., and is operated in cooperation with the Wisconsin Agricultural Experiment Station. This laboratory conducts quality research on barley for both State and Federal programs. The World Collection of barley varieties is maintained and distributed from Beltsville, Md. Federal personnel supervise four spring and four winter uniform nurseries.

In cooperation with the Michigan Agricultural Experiment Station, extramural research is conducted on sources of resistance to the cereal leaf beetle and at Idaho Agricultural Experiment Station, extramural research was completed on the propagation and production of non cultivated species of *Hordeum*.

Two PL 480 projects dealing with research on barley are in operation--in Poland, to find sources of resistance to loose smut in native and foreign barley varieties and to identify genes for resistance by using trisomic lines of barley, and in India, to study the physiology of drought resistance in some crop plants.

The Federal intramural research effort devoted to barley totals 17.3 scientist man-years, of which 8.3 is for breeding and genetics, 3.2 for diseases, 4.0 for quality, and 1.6 for physiology.

There was 0.2 scientist man-year devoted to extramural research in breeding and genetics.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 29.5 scientist man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Hybrid Barley. Studies on self-regulating genetic systems for producing the male and female parental stocks of hybrid barley are progressing satisfactorily. All of the schemes developed so far require the sorting of certain genotypes at one step. This will be accomplished by various means like the use of a chemical, e.g., DDT, aleurone seed color, seed size and shape, plant height, and lethal genes (albino). At the present time, a number of combinations between several genetic systems on the one hand and various roguing means on the other are under development or being tested. The objective here is to get the most favorable combination of factors to do the job at a reasonable cost. The various systems mentioned are being back-crossed into suitable parental stock for use in making hybrids.

2. Female Sterility. Several barley stocks have been found (United States and Canada) where the female sex is sterile and the male is fertile. These types offer the possibility of setting up the male parent of hybrid barley as a balanced tertiary trisomic or one of the alternate schemes. When this is accomplished, it will be possible (with roguing) to mix the seed of the two parents before planting them and then to sow and harvest the crop the same way as is done today for a variety. All the seed harvested under this plan would be crossed seed. The discovery of female sterility is another forward step in the overall plan for hybrid barley that will help to automate the whole process and reduce costs.

3. Stiff Straw. Considerable progress is being made in breeding both spring and winter barleys that have shorter and stiffer straw. The principal sources

of shortness and stiffness of straw are the varieties 'Jotun', 'Belownee', 'Jaydee', and T5-7c. The need for a better straw in barley is assuming greater importance in the light of hybrid barley and the increased use of fertilizers.

4. New Varieties Released. One new variety of spring barley was released this year. 'Primus' was released jointly by the South Dakota Agricultural Experiment Station and the Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture. It combines earliness with high yield, high test weight, heat tolerance, drought resistance, and sufficient disease resistance for South Dakota conditions. Primus was released as a feed barley. Its acceptability for use in malting is being tested and the results will probably be available in 1969.

'Tschermak', a 2-rowed winter barley, was released jointly by the New Jersey Agricultural Experiment Station and Crops Research Division, ARS, USDA. Tschermak was introduced from Austria in 1948. In years when winterkilling is not a factor, Tschermak yields about equal to 'Wong' and 'Early Wong' (other varieties commercially grown in New Jersey), but averages more than three pounds per bushel higher test weight. Severe winters may cause some damage to Tschermak. The principal advantage of Tschermak is that, if handled properly, it can be used for malting, and thus command a premium price on the market over feed barley. At the present time barley used for malting in New Jersey must be shipped from midwestern States.

5. Cereal Leaf Beetle. Two resistant spring varieties of barley (CI 6671 from Iran and CI 6469 from Poland) were found this year in the World Collection. Crosses between these two gave progeny lines that are more resistant than either parent. A technique using adult beetle feeding and oviposition was developed for screening F_2 populations in the greenhouse. Among the winter varieties in the World Collection, the most resistant ones found were CI 9568, CI 11250, and CI 11878.

6. Insect-Host Interaction. The effects of greenbug feeding on resistant and susceptible barley varieties show a remarkable decrease of chlorophyll content in susceptible varieties over resistant ones where the decline was much less and occurred more slowly. Resistance may therefore be an expression of infestation for longer periods of time due to its capacity to maintain a higher chlorophyll content. An increase of phenolic compounds was noted in both susceptible and resistant varieties. This suggests that the 13-fold increase in peroxidase also noted may be because this enzyme uses a phenoxy-like compound as a substrate, and is not related to resistance.

B. Diseases

1. Stripe Mosaic. Studies of the interactions between barley varieties and barley stripe mosaic strains showed that yield losses are correlated with severity of symptoms induced. The yield of the resistant variety 'Moreval', when infected with barley stripe mosaic virus, was not significantly reduced.

Seed transmission of the virus through Moreval was absent or less than 2%, whereas seed transmission through the susceptible variety 'Traill' was 42%. The resistance of Moreval to barley stripe mosaic virus has been transferred to commercially acceptable selections. No barley stripe mosaic virus was found to be transmitted through the seed of plants inoculated less than 8 days prior to fertilization. Some barley stripe mosaic virus strains have been purified by using the local lesion-host Chenopodium.

2. Fungicide Seed Treatment. An oxathiin chemical (2, 3, dihydro-5-carbox-anilido-6-methyl, 4-oxathiin) developed by the Uniroyal Company, reduced the loose smut in plants from 18 to 0%. The malting quality of seed treated with the fungicide was not affected. This and other seed-treatment fungicides are being tested for their control of root rotting, seedling blighting, and leaf spotting fungi.

3. A New Pathogenic Strain of Loose Smut. A new strain of the fungus, Ustilago nuda, was discovered. It is virulent on derivatives from the variety 'Jet' which had been immune to all previous pathogenic strains isolated in North America. The strain was isolated from a plant grown from seed introduced from Ethiopia. Some commercially grown winter and spring varieties were immune to the new pathogenic strain.

C. Quality

1. Effect of Cultural Practices and Environment on Quality. Michigan grown 'Larker' barley was lower in protein modification during standard malting than that from the Red River Valley. The increase in protein modification with gibberellic acid treatments indicated adequate potential. Smut infection in Larker barley seed increased water sensitivity of the grain, but other differences in malting performance and malt quality could not be conclusively demonstrated.

2. Varieties from State - Federal Breeding Programs. More than 3,000 samples from the 1965 crop were received and analyzed but less than 2,000 were malted. The barleys showed water sensitivity, which is unusual for American barleys, heavy microorganism contamination from some locations, and high protein. These factors reduced the number suitable for malting. Promising six-row spring selections were evident from programs at North Dakota, Wisconsin, Michigan, and South Dakota, but some do not fit the 'Trophy'-Larker quality pattern exactly. Several two-row spring selections from the Idaho program are at the increase stage for plant scale industry evaluation. About 50 samples were evaluated through the pilot plant and 80 through the micro-processing equipment. More advanced selections continue to show promise through the more detailed processing evaluation.

3. Quality of Hybrid Barley. Preliminary evaluation of seed from F_1 hybrids showed quality about equal to mid-parent values, except for slightly lower barley nitrogen and slightly larger kernels for the hybrids.

4. Enzymes. Ungerminated wheat and barley showed a nearly even distribution of acidic and neutral peptidases. After germination most of this activity was in the proximal portion of the kernel. Contact with the germ, or closely related tissues appears to be essential for enzyme synthesis. BAPA and BAEE have proven to be the best substrates for study of peptidases and for establishing their physical and chemical characteristics, as well as the linkages hydrolyzed by the enzymes. Adequate extraction and separation techniques have been established.

D. Physiology

1. Winterhardiness Studies. A device and procedure has been developed for classifying the cell wall polysaccharides which are important in determining the winterhardiness of cereals. This method depends on the interaction of the polysaccharides with an expanding ice lattice as the liquid solution slides across the ice-liquid interface. Here, weakly adsorbed polysaccharides are easily swept away while those which interact with the ice lattice tend to be trapped. The latter type are the ones most concerned with hardiness, since their entrapment gives a mushy type of ice that is less effective in causing tissue damage.

A test freezing chamber which can be programmed for temperature and humidity was built. This chamber will be used to test breeding populations, to search for unusual winter-hardy types of cereals in a world collection, and to study the inhibitory activity to freezing of plant extracted polysaccharides.

PUBLICATIONS -- USDA AND COOPERATING PROGRAMS

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CORN AND SORGHUM BREEDING, GENETICS, DISEASES, PHYSIOLOGY, AND CULTURE
Crops Research Division, ARS

Problem. The trend is toward greater dependence on the hybrid seed industry for supplies of hybrid corn and sorghum. This development permits a reorientation of our program giving less attention to developmental breeding and increasing emphasis to basic research in genetics, physiology, and pathology. Improvements in hybrid performance require the development of new and more efficient evaluation techniques. The combined skills of several disciplines may be required to achieve the desired objective. In general, these combinations of skills are not available in any single hybrid seed company. Further developments involving improved techniques, therefore, remain largely the responsibility of the public institutions.

Research along these lines must remain a continuing effort if new problems are to be resolved. This is well illustrated (1) by the recent serious outbreaks of corn viruses, maize dwarf mosaic and wheat streak mosaic in the Corn Belt and corn stunt in the southern States and (2) by the development of strains of the corn rootworm resistant to the commonly employed chlorinated hydrocarbon insecticides. New sources of resistance to these pests must be sought. Work underway suggests that corns may be developed that have improved amino-acid balance. If these characteristics can be incorporated into commercial corn without an important sacrifice in yield then a material increase in livestock-feeding efficiency should result. Additional information is needed on genetic control of biosynthesis of oil, protein, and carbohydrates as well as other important constituents to aid in the development of new types that have greater nutritional or industrial potential. New sources of resistance to disease and insect pests are needed together with information on mode of inheritance and the chemical basis for resistance. A more adequate explanation for heterosis also remains a continuing problem.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program that involves geneticists, physiologists, pathologists, and agronomists who are engaged in basic and applied research related to the improvement of corn and sorghum. Corn research is conducted at Beltsville, Md., and Charleston, S. C. In cooperation with State Agricultural Experiment Stations at Tifton, Ga.; Urbana, Ill.; Lafayette, Ind.; Ames, Iowa; State College, Miss.; Columbia, Mo.; Raleigh, N. C.; Wooster, Ohio; Brookings, S. Dak.; Knoxville, Tenn.; and Madison, Wis., research on corn is also carried out. Sorghum research is being conducted at Mayaguez, P. R. and in cooperation with the State Agricultural Experiment Stations at Manhattan and Hays, Kans.; Lincoln, Nebr.; Stillwater, Okla.; and Chillicothe and College Station, Tex. In Africa research on improvement of corn, sorghum, and millet is being conducted under an agreement with the Agency for International Development.

Cooperative agreements in the following States involve corn research: Illinois, genetic control of fatty acid synthesis and protein synthesis in corn, and the storage of proteins in corn; Indiana, use of plant tissue cultures for the study of starch biosynthesis; Iowa, types of gene action involved in the expression of quantitative traits; and with the Entomology Research Division, biochemical resistance to corn borer; Missouri, with the Entomology Research Division, resistance to the corn earworm; North Carolina, relation of variation in chromosomal morphology to inheritance in maize. Research involving sorghum includes a contract at Arizona on resistance to the charcoal rot disease and a cooperative agreement to continue charcoal rot studies, and at Nebraska and Kansas cooperative agreements involving quantitative genetic studies.

Fifteen PL 480 projects dealing with corn and sorghum research are in operation. In India, projects deal with corn and sugarcane genetics; basic research on carbohydrate metabolism; the genetic effects of radiation; storage, maintenance, and distribution of millets germ plasm; cataloguing and classifying genetic stocks of sorghums; chemical composition of pearl millet; responses of various corn and sorghum germ plasm sources to agronomic practices; investigations on diseases of sorghum and other important millets; research on maize diseases with special reference to Erwinia carotovora var. zeae; and studies on Helminthosporium species of corn and sorghum. In the Philippines, there is research on downy mildew of corn; in Yugoslavia, on classification and evolutionary relationship of local germ plasm; on leaf redness in corn; and on breeding corn for high oil and protein content. In Brazil, Latin American corn germ plasm is being evaluated for U.S. use.

The Federal research effort in the United States devoted to corn and sorghum totals 41.1 scientist man-years. In intramural research, 20.7 SMY are devoted to breeding and genetics; 8.6 to diseases, 0.2 to quality, and 7.9 to culture and physiology. In addition, 5 scientists conduct research in Africa on corn, sorghum, and millet. Of these, 3.5 SMY are devoted to breeding and genetics and 1.5 to diseases.

Of the 3.7 scientist man-years in extramural research, 1.8 is devoted to breeding and genetics, 0.9 to diseases, and 1.0 to physiology and culture.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 152.8 scientist man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Corn Genetics. Basic genetic studies are underway at Ames, Iowa; Beltsville, Md.; Columbia, Mo.; and Raleigh, N. C. Research involves three separate areas: classical genetics and cytogenetics, biochemical genetics,

and quantitative genetics. These have the common objective of a more complete understanding of the principles underlying the improvement of corn.

a. Classical genetics and cytogenetics. In most organisms DNA is the carrier of the genetic information. In the plant viruses thus far studied DNA is absent and RNA plays this same role. The possibility exists for interaction between these two coding systems. The progenies of plants infected with Barley Stripe Mosaic Virus (RNA) exhibit several types of genetic modifications. These include "aberrant ratio" and mosaic and navajo mimics. Each of the mimic types appears to give rise to new genetic changes simulating known mutable systems. These genetic effects are tentatively explained by the assumption of a episome-like particle induced in some unknown fashion by the interaction of host DNA and virus RNA.

Chromosomal structural rearrangements may either impede or enhance synapsis. If the effects of radiation may be explained on a one-hit-two-breaks mechanism rather than on an intrachromosomal basis, the result could be either a deletion and a ring or a small inversion. Results are being explained on the assumption that deficiencies impede and inversions enhance synapsis. This hypothesis may also explain the differential pairing observed among standard genetic stocks. Preliminary data suggest that intermittent DC fields can cause chromosome losses and possible breakage. Isogenic lines are being developed that involve the presence and absence of abnormal 10. These stocks will be used in an extensive study on the effects that linkage disequilibrium has on generation means or variance estimates.

b. Quantitative genetics. Epistasis is one of the common types of gene actions encountered in qualitative traits. Comparable studies on quantitative traits fall into two groups. In those where variance component estimates are used, estimates for epistasis are minimal and when the generation mean approach is used, estimates for epistasis are often significant. Such differential results appear to be due in large part to the models and techniques used. More comprehensive trials that involve single, three-way, and double crosses should help to clarify this situation. A combination of inbreeding and selection based on the performance of paired plant reciprocals provides evidence for significant improvement. This breeding method would be expected to have maximum efficiency if epistasis or overdominance were of major importance in heterosis. Three cycles of recurrent selection for resistance to stalk rot indicate marked progress and that gene action was primarily additive. Mean ratings (1 - 6 scale) were 3.7 for C₀ and 1.7 for C₃. Studies on intra-line variability were continued. Significant variation was found among sub-lines and sub-line crosses for nearly all characters studied. Intra-line differences among Rf and rf sublines were significant in the majority of the comparisons. These differences must have arisen from relic heterozygosity or mutation.

c. Biochemical genetics. Bacteria, fungi, yeasts, and algae have been favored organisms for biochemical genetic studies. In spite of their economic importance comparable studies with higher organisms have been limited.

Extensive genetic data are available on differences among carbohydrates, oils, proteins, carotenoids, and anthocyanins and studies are underway to relate these differences to biosynthesis. Gene action sequence has been established for the anthocyanin series as follows: $C^I-C_1-C_2-R(In)-A_1-A_2-Bz_1-Bz_2$ -anthocyanin. Thin layer chromatography indicates the presence of isoquercitrin and quercitrin in bz_2 and probably quercitrin in a_1 and a_2 . The amino acid phenylalanine is a precursor of the B ring in anthocyanin. The enzyme, phenylalanine-ammonia-lyase, which converts phenylalanine to cinnamic acid has been isolated and partly purified. Search is underway for other enzymes which may be intermediary in anthocyanin synthesis.

2. Dent Corn Breeding.

a. Breeding stocks released. Thirty-eight breeding stocks were released from Federal - State cooperative breeding programs. Sixteen synthetics were released from Iowa. These represent elite germ plasm that may be useful in breeding superior inbred lines and hybrids. Sixteen lines possessing high-amylose starch were released from Missouri. These range from 60 to 80% amylose while normal corn exhibits about 27%. Five dwarf lines were released from Mississippi. These were developed through the introduction of the brachytic₂ gene into standard lines. Hybrids involving these lines compare favorably in yield with their normal-height counterparts. A cytoplasmic sterile and a non-fertility restoring strain of K55 have been released jointly by Kansas, Missouri, and Ohio.

4. Sorghum Genetics. Genetic and breeding studies are underway at each of the locations where cooperative work is in progress. Cytogenetic studies are predominate at College Station, Tex.; disease resistance at Manhattan, Kans., and College Station, Tex.; genetics of morphological and physiological traits at Hays and Manhattan, Kans., and Lincoln, Nebr. An asynaptic stock has been used as a source of primary trisomes. In some, transmission rates are low and such stocks can be maintained only with difficulty. Eighty-nine homozygous translocation stocks have been identified. Over 300 intercrosses have been made which will aid in the identification of the specific chromosomes involved. Intercrosses of translocations and trisomics now under study should also aid in chromosome identification. Mutation conditioning resistance to Periconia occurs with an average frequency of 1 in 7880. Data on inheritance suggest that only a single locus is involved. Some differences exist among mutants so the locus may well be compound. The dwarfing gene, dw₃, is also unstable and frequently reverts to DW₃. Studies of a series of such reversions are underway.

5. Sorghum Breeding. Fifteen lines of sorghum were released from the Kansas program. Ten of these were developed in the cooperative program at Manhattan and five at Hays, Kans. Five of these are B lines and the remaining ten are R lines. All possess good combining ability and some have resistance to head smut and are chinch bug tolerant. A segment of the World Sorghum Collection was grown at Isabela, Puerto Rico, for seed increase and storage at the

National Seed Storage Laboratory at Ft. Collins, Colo. An additional generation of backcrossing was obtained in the conversion program underway in Puerto Rico. Seed for both the conversion and increase programs came from a PL 480 project in India.

B. Diseases. The virus diseases of corn and downy mildew of sorghum were of major concern in 1966.

1. Corn Diseases.

a. Viruses. At least three distinct viruses attacking corn have been identified. These are corn stunt, maize dwarf mosaic and wheat streak mosaic. Two distinct strains of maize dwarf mosaic exist. One form is carried by Johnsongrass and can be found from Tennessee and Arkansas northward throughout the Johnsongrass territory. New sites for this disease were reported in 1966. The second form does not attack Johnsongrass and occurs north of the Johnsongrass belt. Both strains are mechanically transmissible and aphids act as the natural vectors. The overwintering host of the non-Johnsongrass strain is unknown. Wheat streak mosaic also occurs in greatest abundance north of the Johnsongrass belt. This virus is mechanically transmissible and also has the leaf curl mite, Aceria tulipae, as the vector. Kernel red streak is associated with feeding by this mite but appears not to be associated with the virus. Sources of resistance have been found for the two strains of maize dwarf mosaic but little information is available on resistance to wheat streak mosaic or kernel red streak. Corn stunt appears to be limited to Mississippi, North Carolina, and other States in the South. It has been found in most of the southern States. Losses continue to be high in the Yazoo Delta area, corn acreages having decreased two-thirds in the last three years. Transmission is by leafhoppers, and Johnsongrass serves as the overwintering host. The known vectors include species of Dalbulus and Graminella nigrifrons. The latter is an inefficient vector but because of its abundance it accounts for the early-season spread. Sources of resistance to stunt are available. A mechanically transmissible virus also occurs throughout the same geographic area as stunt. Symptom expression differs markedly from maize dwarf mosaic but the possible relation between these two viruses remains unclear. Several other viruses that attack corn have been observed but, as yet, none of these have caused serious losses. A PL 480 project in Yugoslavia deals with a virus disease of corn. The relation between this leaf redness in Yugoslavia and the rough dwarf mosaic in Israel (PL 480 project sponsored by the Entomology Research Division) and the viruses under study in the United States has not been fully explored.

b. Gibberella ear rot. Three methods of artificial inoculation with Gibberella zeae were compared. They were: (1) spraying a spore suspension on the silks, (2) injecting a spore suspension into the ears, and (3) insertion into the ear tip of toothpicks over which G. zeae had grown. Inoculations were made at 3 dates: 2 days after full silk, 2 weeks later, and 4 weeks later. Spray inoculation shortly after silking appears to be the most efficient technique.

c. Helminthosporium. No major outbreaks of this disease occurred in 1966. Comparisons involving monogenic and polygenic resistance to this disease gave no clear evidence for superiority of either type.

d. Downy mildew. Sclerospora sorghi has been reported from Texas and Mississippi and appears to be increasing on both corn and sorghum. Resistance to this disease was observed in the Philippines (PL 480 project) and these resistant types are under observation.

2. Sorghum Diseases. Charcoal rot (Macrophomina phaseoli), head smut (Spacelotheca reiliana), and downy mildew (Sclerospora sorghi) received major attention during 1966.

a. Charcoal rot. Field studies on charcoal rot have been conducted under a contract with the University of Arizona. The expression of susceptibility to charcoal rot depends on a combination of factors including the stage of grain development, high temperatures, and water stress. In Arizona these variables can be partially controlled under field conditions. Eighty-three items have been evaluated for susceptibility. Variability is great both between and within selections. Because of lack of precise environmental control the evaluation of variation in resistance or susceptibility may require screening under different environments.

b. Head smut. Several strains are now available which possess a satisfactory level of resistance to head smut. Resistance phases of this work are complicated by a poor germination of chlamydospores. Spores from young sori, 11 to 13 days of age, have the highest percentage germination but even under these conditions, less than half of the spores germinate. No treatments thus far tried have given good uniform germination. Studies on the inheritance of resistance and the identification of new sources of resistance are hampered by inadequate inoculation techniques.

c. Downy mildew. Downy mildew is most serious on forage sorghums but will also attack grain and broomcorn types. This disease was first observed in Texas in 1961, and has continued to spread since that date. Resistance was found in some items of the World Sorghum Collection (PL 480 project in India) when grown in Nigeria. Breeding and inheritance studies involving this material are currently in progress.

C. Physiology and Culture

1. Corn.

a. Protein synthesis. Three ribonucleases (RNases) have been identified in corn. RNase A has a molecular weight of 23,000, liberates cyclic nucleotides and hydrolyzes cyclic adenosine and guanosine phosphates; RNase M has a molecular weight of 17,500 and liberates cyclic nucleotides; RNase B has a molecular weight of 32,000 and liberates 5' nucleotides. High levels of

RNase have been found to be associated with the opaque₂ but not the floury₂ mutant. Both mutant types are characterized by reduced zein and increased lysine levels. Results from other types indicate a relation between RNase activity and protein percentage. The mechanism involved, however, remains unclear.

b. Fat synthesis. Several general relations have been noted. An increase in oil content is accompanied by an increase in oleic acid. The percentage of oleic acid among strains ranged from 10.5 to 37.1 and of linolenic acid from 47.3 to 70.0. The sum of these two totals between 80 to 85% of the total fatty acids. The lipid classes of the developing corn kernel were studied by means of column and thin layer chromatography. At 10 days after pollination polar lipids, phospholipids and glycolipids make up 75% of the total lipids. At maturity the triglycerides make up 85% of the total lipids. Palmitic acid occurred as a major constituent of the polar lipids within the first 20-days. At later stages the percentage of palmitic and linolenic acids decreased in both the triglycerides and polar lipid fractions. Fatty acid placement on the triglycerides molecule appears not to be random. More oleic and linoleic acids were found at the number 2 position than would be expected by chance.

c. Carbohydrate synthesis. Numerous genetic characters affect the characteristics of storage end-product, starch. The biosynthetic pathway for the differing carbohydrate types remains unclear. Methods have been developed for a stepwise extraction, fractionation and quantitative measurement of glucose, fructose, sucrose, water soluble polysaccharides, and starch. With these procedures available glucose -C¹⁴ was used to study the early intermediates in the conversion of glucose to starch. With increasing periods of incubation, radioactivity was transferred to sucrose and, to a lesser extent, starch. Additional studies involving tissue slices rather than whole endosperms are in progress. Such studies should resolve the question whether sucrose is an intermediary or merely a rapidly synthesized product held in a labile pool. An attempt is being made to use tissue cultures of developing endosperms to provide a continuing supply of material for analytical studies.

d. Mineral nutrition. Inbred lines of corn differ in their response to mineral deficiencies. Ia.B8 and WF9 exhibit typical magnesium deficiency symptoms when grown at low magnesium levels. Ia.B8A and Oh40B appear normal under the same conditions. This differential response is not related to magnesium absorption but appears to be related to its mobility within the plant. A deficiency for one macro-element appears to affect absorption or accumulation of other elements and may be accompanied by a modification of the types of organic acids present. This same relation was absent or much less marked in the micronutrient deficient groups.

2. Sorghum. Physiologic studies with this crop are concerned with heat and drought tolerance, photosynthesis, and translocation of metabolites. Differences among lines and hybrids in heat tolerance are quite marked. Hardening appears to be an important factor as all types exhibit more tolerance under hot July than under cooler August conditions. Work continues on a microwave refractometer to measure water potential in plant material. Technical problems relating to stabilizing electronic circuitry and temperature in both circuitry housing and test cavities are receiving further attention. Photosynthetic rate measurements have been made on leaves and heads using an infrared analyzer. Comparisons were made between compact (RS610) and semi-open (DeKalb E57), head types. At anthesis photosynthetic CO_2 uptake slightly exceeded respiratory CO_2 evolution in the compact head. Photosynthetic rates were much higher in the semi-open head types. In both types CO_2 uptake declined markedly from anthesis to the hard dough stage. Studies on translocation of metabolites involve use of C^{14}O_2 . Shifts in allocation of photosynthetic products to different plant parts varies with stage of plant growth.

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WHEAT AND RYE BREEDING, GENETICS, DISEASES, QUALITY,
PHYSIOLOGY AND CULTURE

Crops Research Division, ARS

Problem. Because wheat is extensively grown in the United States and is widely used as human food, every effort should be made to develop practices that will enable farmers to produce a better crop at lower costs. To do this more basic information is needed on plant factors and other elements involved in producing high yields, more resistance to diseases, and more nutritious grain. With the sure knowledge that heterosis exists in wheat, more attention should be turned toward developing hybrid wheats that may be utilized profitably and economically. A great deal of additional information is needed to establish this event firmly and to insure its continuity. A vast number of questions need to be answered and urgent biological problems present themselves, such as, the factors and the types of gene action involved in heterosis, the mechanisms of sterility and restoration of fertility, and those of mutation and/or gene interaction that go to produce new and higher levels of nutrition, and the stability of improved quality.

Wheat is susceptible to a number of diseases that cause consistent small losses and occasional heavy ones. New sources of pest resistance and basic information are needed on diseases such as stem rust in the Plains, stripe rust and root rots in the Northwest, septoria and mildew in the East and Southeast. Also, continued efforts are necessary to prevent losses from insect pests such as the hessian fly, sawfly, the cereal leaf beetle, and aphids. Each disease and pest should be investigated thoroughly to discover ways to reduce the damage it brings.

Rye as a grain and forage crop is seriously threatened by Anthracnose which has caused widespread losses in the Eastern States, and by other diseases.

All of these problems have a far reaching impact on food production, quality, nutrition, and economic utilization of wheat and rye.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program of research leadership in wheat investigations involving basic and applied research in the sciences of agronomy, pathology, chemistry, genetics, and statistics. Regional and national leadership is given to several phases of the work.

Federal research is concentrated at eight centers, but 14 other locations are required either to provide proximity to the problem or to utilize facilities and contacts with cooperating workers at such locations. At Beltsville, Md., research is conducted in breeding and genetics, diseases, and physiology. In cooperation with State Agricultural Experiment Stations;

research in breeding and genetics is conducted at Mesa, Ariz.; Tifton, Ga.; Aberdeen, Idaho; Lafayette, Ind.; Manhattan, Kans.; East Lansing, Mich.; St. Paul, Minn.; Columbia, Mo.; Bozeman, Mont.; Lincoln, Nebr.; Fargo, N. Dak.; Stillwater, Okla.; Corvallis, Ore.; Pendleton, Ore.; Brookings, S. Dak.; College Station, Tex.; and Pullman, Wash. Research in disease work is conducted at Tifton, Ga.; Aberdeen, Idaho; Urbana, Ill.; Manhattan, Kans.; St. Paul, Minn.; Bozeman, Mont.; Lincoln, Nebr.; Fargo, N. Dak.; Stillwater, Okla.; Corvallis, Ore.; Mayaguez, P. R.; Brookings, S. Dak.; College Station, Tex.; and Pullman, Wash. Research on quality is conducted at Manhattan, Kans.; Fargo, N. Dak.; Wooster, Ohio; and Pullman, Wash. Research in physiology and culture is conducted at East Lansing, Mich.; Bozeman, Mont.; Lincoln, Nebr.; Corvallis, Ore.; Brookings, S. Dak.; and Pullman, Wash. Insect resistance and related genetics, physiology and pathology studies are conducted in cooperation with ENT at Brookings, S. Dak.

During the year, 13 grants or special cooperative agreements were in force or were initiated. Basic breeding and genetics studies were conducted in four States: Idaho, a contract terminated on methods and techniques of propagating non-cultivated varieties; Nebraska, the relation of quality in hard winter wheat to specific chromosomes; Oklahoma, nature of resistance to the greenbug (with ENT); and Wisconsin, a new understanding of cell growth and differentiation through chromosomal responses of plant heterokaryons. Five extramural projects in four States related to diseases: Nebraska, grant research was completed on determination of the role of indolacetic acid in the plant on its reaction to stem rust, and a new cooperative agreement was initiated on interactions between nucleic acids of cereal viruses and their hosts; Oregon, germination inhibitors of bunt spores; North Dakota, the factors that determine resistance of durum wheat to black point disease; and Pennsylvania, ultrastructure of the host-parasite relationship in the stem rust disease. In four States extramural research was conducted on quality: Illinois, genetic and environmental control of wheat metabolism, especially nitrogen reductase activity; Kansas, genes that cause an alteration of the chemical composition of grain; Montana, the biochemical basis for quality differences on whole grain and milling fractions of monosomic lines; and North Dakota, the contribution of water soluble proteins to quality.

Nine PL 480 projects on wheat and rye include the following: in Spain, polyploidy in rye, and cereal rusts; in Egypt, cereal rusts and smuts; in Pakistan, cereal rusts and smuts; in Israel, origin of cereals; in India, three rusts of wheat; in Yugoslavia, leaf and stem rust resistance, and branching spike types of wheat.

There are 49.5 scientist man-years assigned to the intramural program of which 16.7 are for breeding and genetics, 15.7 for disease, 11.2 for quality, and 1.2 for culture and physiology research.

The extramural research effort devoted to wheat totals 4.74 SMY of which, 1.51 are for breeding and genetics; 1.21 for diseases; 1.04 for quality; and 0.98 for physiology and culture.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 71.0 scientist man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. New Varieties and Germ Plasm Released. 'Parker', a hard red winter wheat, was released jointly with the Kansas and Missouri Agricultural Experiment Stations. It was bred in Kansas. Early maturity, good yield, strong gluten type, and resistance to soilborne mosaic, wheat streak mosaic, stem rust, bunt, and loose smut mark Parker as a major advance.

'Scout 66', a hard red winter wheat, was released jointly with the Nebraska Agricultural Experiment Station. It embodies the chief characters of the parent variety, 'Scout', from which 85 uniform selections were isolated and then composited after testing.

'Guide', a hard red winter wheat, was released jointly with the Nebraska Agricultural Experiment Station. It is early maturing and has adult plant resistance to stem rust.

'Riley 67', a soft red winter wheat, was released jointly with the Indiana Agricultural Experiment Station. It resembles 'Riley' but combines the high degree of leaf rust resistance obtained from Aegilops umbellulata by way of the variety 'Transfer'.

'Federation 67', a soft white spring wheat, was developed in Idaho with collaborative testing by ARS. It has resistance to stripe rust.

'Maricopa', a semi-hard to hard white spring wheat, was developed in Arizona jointly with ARS. It is a stiff-straw semidwarf variety well adapted to irrigation.

'Moran', a hard red spring wheat, was released jointly with the Idaho Agricultural Experiment Station. It has special utility under irrigation where it gives high yields of good breadmaking grain. It is resistant to common forms of stripe and stem rust.

2. Cereal Leaf Beetle Resistance Manifest for Third Year. Winter wheats previously classified as resistant were retested in 1966 with the following results by groups: 52% resistant from 1965, 37% resistant from 1964, 74% resistant Triticum species from 1965. In contrast, a new unscreened group of introductions showed only 4% resistance. Among spring wheats, 71% of the species entries were again resistant. Non-preference to oviposition was an important basis for resistance and this was associated with leaf hairiness. (Cooperative with ENT, New Crops, and Michigan and Indiana Agricultural Experiment Stations)

3. Increase of Triticum Species Completed. The wheat species, exclusive of T. durum and T. aestivum, consisting of about 1,000 entries, was propagated for cereal leaf beetle and other experiments under a contract with the University of Idaho. Many of these have a fragile rachis or are generally unproductive. Propagation of at least 2 pounds of each line was completed.

4. Variety-Environment Interaction for Yield Shown. A statistical analysis of 30 years of data was initiated to obtain new estimates of variety-environment responses. Variety performance in hard winter wheat southern regional trials reveals that some varieties are relatively better yielders under austere environments whereas others make their best relative showing under circumstances that favor high yield levels. 'Pawnee' and 'Early Blackhull' illustrate the first group whereas 'Comanche' falls into second. Some newer varieties are placed in a third grouping superior over the entire environmental range. This group includes Scout and possibly 'Gage' and 'Caddo.' In northern regional trials 'Yogo' appears relatively superior to Cheyenne and Warrior when the general yield level averages about 16 bushels per acre or less but is relatively poorer than these varieties when conditions favor yields of 20 to 30. Linear regressions based on the yield of selected varieties in relation to the nursery mean yields were utilized in making these determinations of regional behavior.

5. Increased Variability from Species Crosses. To transfer sawfly resistance to a common winter wheat and at the same time obtain a good winter-habit feed wheat, Yogo winter wheat was crossed with five tetraploids. Wide segregation occurred for several characters, including spike types, awn expression, kernel weight, protein content of the grain, and glume color; many plants were unlike either parent in one or more characters. Segregates with solidness of stem appeared in the progeny of all five crosses, although all of the wheats used as parents had hollow stems. Considering the variety of genotypic and phenotypic expressions, crosses between many hexaploid and tetraploid wheats now available may supply a large, productive reservoir from which to select desirable plant characters.

6. Pollen Dispersal Studies Conducted. Successful cross-pollination for the production of hybrid seed in crossing fields requires adequate dispersal of large numbers of pollen grains. In studies in Montana, pollen dispersal was measured by exposing slides coated with petroleum jelly a few inches above and below the wheat heads. The number of pollen grains falling on 112

square millimeters of exposed slide were then counted each day. The number of pollen grains on the top slide represented pollen levels in the air and was subtracted from the number counted on the lower slide, to give the amount shed by the variety being measured. Varieties differed significantly at the .01 probability level in pollen production. Pollen shedding is the result of a number of factors. Among these are: amount of pollen per anther, extrusion of the anther from the floret, temperature and humidity, number of heads per unit area, and number of florets per spikelet.

7. Hybrid Wheat Reaches Critical Field Plot Trials. Commercial and public agencies made field trials with hybrid seed produced by using the male-sterile restorer mechanism. Heretofore, heterosis studies have been based on hand-crossed seed. Seed-set was variable, leading, in many cases, to unsatisfactory behavior and yield.

8. Durum Variety Type Being Altered. Semidwarf durums only half as tall as old varieties have been fixed. In North Dakota they generally gave lower yields than medium height varieties and must be improved further. Foliage diseases, notably septoria, contributed to the poor performance. Long day versus insensitive day length durum varieties were up to 60 days apart in heading in Mexico but only 3 to 4 days apart at Langdon, N. Dak.

9. Better Genetic Background for Nullisomic 5B. The absence of a single gene on chromosome 5B enables wheat chromosomes to pair more freely with their homoeologues in other genomes and with genomes of wheat relatives. Nullisomic 5B, while effective, is a dwarf and is male-sterile. Mutants from X-ray treatment among wheat-rye hybrids were sought; that might be normal except for the locus concerned. Eleven cytologically promising ones were found in a preliminary experiment but the plants were inviable from colchicine effects. An improved approach is planned from which viable lines can be established.

10. Machine Processing of World Collection Listings. The project of making punched cards for each entry in the Collection is about 50% complete. Master cards have been completed for 16,000 of the 19,500 wheats. These cards are now being used to prepare varietal lists and descriptive data. When there is a card for each entry in the Collection all varietal lists and other listings of the Collection will be done by means of the punch card.

11. New Ramified Spike Types Acquired. Branch-headed spike types in a hexaploid form were obtained from Yugoslavia (PL 480) and from Italy. These are available for genetic and breeding studies.

12. Rye Inbreeding and Variety Development. 'Gator' rye inbred selections continue to show good resistance to leaf rust and mildew in Georgia. The next task will be to test these many inbred lines to Anthracnose as soon as testing methods can be worked out. Gator inbreds were observed and self-pollinated in 3,300 rod rows. Seeds were obtained from 9,876 self-pollinated plants. It is hoped that testing methods for Anthracnose and

possibly *Helminthosporium* will be worked out soon so that these lines can be used while the seeds are still viable. Another inbreeding nursery called the All-Rye Nursery consisted of all foreign ryes and domestic varieties except Gator. It consisted of 2,980 rows. Selfed seeds were obtained from 3,262 plants.

13. Tetraploid Rye Studies Successfully Concluded. Work in Spain (PL 480) with doubled U.S. varieties indicated an inverse relation between self-incompatibility of the diploid and tetraploid forms of the same variety, i.e., if the diploid was self-sterile, the tetraploid tended to be self-fertile. From 23 original diploid varieties, 9 gave productive tetraploid families. These were more vigorous, more frost resistant, and had less bird damage than their diploid counterparts. Six synthetic varieties were built from the material available. This project was concluded.

14. Distribution of Wild Wheats as to Related Domestication. The distribution of present wild forms may provide clues to the regions of early cereal domestication. PL 480 research in Israel suggests that emmer was domesticated in southeast Turkey. Introgression of chromatin from *aegilops* contributed to the early forms of wheat.

15. Semidwarf Hard Red Spring Wheats Make Progress. Thirty-eight experimental lines were grown at St. Paul, Minn., for the first time in a yield test. These selections represent 12 different crosses. Some of the selections had satisfactory test weights, although there were a few that showed a weakness for this trait. Most selections possessed adequate stem and leaf rust resistance. Three lines were five days earlier than 'Chris'. Also, eight selections were day-light insensitive in Mexico.

16. Progress with Club Wheats Difficult Due to Multiple Problems. Progress in breeding for low viscosity club wheats has been hampered by the recent outbreak of flag smut. Most of the high yielding stripe rust and foot rot-resistant soft clubs were highly susceptible to flag smut. Consequently, the advanced generation 'Omar'-background soft clubs will probably have to give way to early generation clubs having flag smut resistance derived from 'Gaines', 'Burt', or even more resistant parents. 'Suwon' x Omar, soft clubs, which are flag smut-susceptible, may be required for emergency use. A stripe rust-resistant club will be needed in the areas where 'Moro' lodges severely when sown early in the fall. The soft white common wheats appeared to have been damaged less from the 1966 attack of diseases in the Pacific Northwest.

B. Diseases

1. Oxathiins for Disease Control Give Dramatic Results. Two Uniroyal Company materials have been evaluated. D-735 (2, 3-dihydro-5-carboxanilido-6-methyl-1, 4-oxathiin) reduced loose smut infection from 14% in the check to 1 head among 5,000 stems in Texas. Also, as a seed dressing, it gave

good control of seed-borne stinking smut and at quite high rates reduced the soil-borne infection in Washington. F-461 (2, 3-dihydro-5-carboxanilido-6-methyl-1, 4-oxathiin-4, 4-dioxide) was less effective for the smuts and would be classed unsatisfactory.

Greenhouse evaluation of soil treatments with various compounds in Minnesota for control of stem rust infection in wheat seedlings has demonstrated that several had some effectiveness, but none was as active as the dioxide derivative of oxathiin (F-461).

Control of leaf and stem rusts of wheat by soil applications of F-461 was demonstrated in field tests. Yields of wheat were as good for a treatment consisting of 4 lb/A of F-461 applied to the soil at planting plus a foliar spray of 2 lb/A of the same compound at mid-season as for a treatment consisting of two sprays of 3 lb/A RH 539, the formulation of nickel sulfate plus maneb.

2. Flag Smut Spores Viable after Ten Years -- Non-viable at Twenty Years. In the late 1940's, spores of Urocystis tritici were collected from seven countries by A. G. Johnson. Some of these spores had been stored dry in glass bottles in a refrigerator for about 20 years and were tested in 1966. Several methods were used to determine whether or not any of the spores were viable. All of the tests used failed to show any germination. These spores retained their viability for 10 years, but all viability appears to have been lost by the 20th year of such storage.

3. Liquid N Storage of Pathogens Extended. Cultures of different fungi, other than rusts, stored in liquid N were checked for viability. All fungi survived after 12 months of storage. S. rolfsii when stored as hyphae and mature sclerotia did not survive; whereas, immature sclerotia were viable after 12 months of storage in liquid N.

4. Powdery Mildew Tester Stocks Developed. Eleven 'Chancellor'-type lines that possess single specific genes for resistance to powdery mildew have been developed by backcrossing. Four of these have gene Pm1, and two have gene Pm2, three have gene Pm3, and two have gene Pm4. These near-isogenic lines are of value for genetic, linkage, breeding, and mildew culture studies. Other materials are under development. Pm1 to 3 have been associated with chromosomes 7A, 5D, and 1A, respectively.

5. Root- and Foot-Rot Diseases Identified. Examinations of fields of winter wheat in the Pacific Northwest during 1965 and 1966 confirmed that Fusarium root- and foot-rot and Cercospora foot-rot are the important foot-rot diseases of wheat in the Pacific Northwest. For the first time on record, fields in the Pullman, Wash., area showed severe damage due to Fusarium culmorum. Other F. culmorum infestations were discovered this year in other parts of Washington as well as Oregon, Idaho, and Montana. Infestations discovered last year still persist. F. graminearum, heretofore not

known to occur in Washington, was found in 1966. Foot-rot symptoms produced by this fungus on wheat are proving similar to those produced by F. culmorum, which infects winter wheat primarily during early tillering and crown root formation. Entry is gained through infected crown roots or through openings made by roots during their emergence from the crown. Crown rot then becomes extensive. Whole plants finally die during late spring and early summer, giving the so-called prematurity plant blight or white heads.

6. Yellow Dwarf Virus Disease Resistance and Damage Noted. Barley yellow dwarf virus infection caused pronounced reductions of growth in spring wheat at Brookings, S. Dak. (Cooperative with Entomology Research Division). Ten varieties, seeded uniformly, were given two treatments, (1) infested with viruliferous aphids, and (2) uninfested. Both were sprayed with dimethoate insecticide several times following infestation. Yields were reduced 50-75%, height was reduced about 33%, heading date was delayed about three days, and chlorophyll in flag leaves was reduced about 33-50%. In an extensive test of 26 varieties, 3 had less than 40% decrease in yield because of virus infection, 13 had decreases of 40-60%, and 10 had 60-84% reduction in yield. Those least affected were Wisconsin 262, C.I. 13946, and C.I. 13775. In preliminary studies P.I. 10646 was the least affected of all wheats observed. P.I. 124819 and P.I. 117807 exhibited resistance and are also of special interest for resistance work.

7. Ohio-Indiana-Illinois Virus Identified as Streak. Purified streak virus has been injected into five rabbits and the antiserum obtained. This antiserum was used to identify field collections of virus from Ohio, Indiana, and Illinois as the wheat streak mosaic virus.

8. Soil-Borne Wheat Mosaic Transmission Points to Fungus as Vector. Seedlings that were inoculated by pouring inoculum directly into the soil in which they were growing showed more soil-borne mosaic than seedlings inoculated in petri dishes. A heavier initial infection of primary roots with Polymyxa graminis occurred if seedlings were inoculated when 4-5 days old than if inoculated when 2 days old, although the virus often remained localized in the roots when older seedlings were inoculated. Root washings of plants grown in sand were not as good a source for inoculum as those from plants grown in soil. Seedlings inoculated in sand became infected less readily than those inoculated in soil. Soil or a mixture of soil and sand was the best potting medium in which to grow wheat plants to maintain P. graminis and the soil-borne wheat mosaic virus. The soil-borne wheat mosaic virus appears to be firmly attached to the fungus zoospores, or inside them, because it cannot be removed from the zoospores with repeated centrifugation nor inactivated by antibodies to the virus.

9. New Approach to Pathogenicity of Leaf Rust Organism Introduced. The unified and standard sets do not adequately describe the pathogenic potential of the North American leaf rust pathogen population. This is shown by the predominance of UN 2 in the 2,029 isolates studied and the distinct differentiation of the cultures by the NA 65 supplemental differentials. UN race 2

was associated with NA 65 races 3, 11, and 12; these races are differentiated critically by the wheat varieties 'Lee' and 'Exchange'. The fluctuations in the pathogen population in the central part of the United States is apparently largely influenced by specific resistance genes of 'Selkirk', which is thought to be derived from or related to Lee and Exchange. UN race 9 was associated completely with NA 65 race 1 in this sampling.

For use in plant breeding for specific resistance to leaf rust, the data from assays of pathogenic potential must be reduced to virulence to single varieties. It seems more logical to present the data in that way rather than as race frequency data. These data show that virulence to 'Democrat', Lee and 'Sinvaloch' is currently at a very high frequency. The frequency of virulence to exchange fluctuates from year to year; that to 'Waban' is low and is associated with UN race 13. Virulence to 'Dular' was not observed last year.

10. Head Infection of Stripe Rust Inversely Related to Plant Height. A comparison of short, medium, medium tall, and tall isogenic lines of Suwon 92/Burt BC 5 revealed stripe rust infection percentages of 62.2, 54.4, 46.4, and 13.5%, respectively. The relationship of infection to plant height was not complete since moderately wide ranges for severity of infection occurred among isogenic lines within a particular height group. Tests at Pullman, Wash., established head type, awn expression, and plant stature as being important attributes of head infection. The effects may be direct, indirect, or a combination of both.

11. Flag Smut Spreading, Control by Chemicals and Resistance. The presence of flag smut has been established in eight counties in Washington (Adams, Columbia, Garfield, Lincoln, Klickitat, Walla Walla, Whitman, and Yakima). Flag smut also occurs in two counties in Oregon (Umatilla and Wasco). Relatively good control of flag smut was obtained from the use of tetrachloro-nitroanisole (TCNA), Ceresan L, and the Hercules formulations (at the higher rates only) in tests conducted in contaminated soil near Goldendale, Wash. Other seed-treatment fungicides failed to provide adequate control.

Flag smut failed to develop in only 3 of 56 entries submitted for evaluation against flag smut in the field at Goldendale. The apparent resistance of these 3 wheats can be traced to Burt in 2 entries and to 'Norin 10'/'Brevor-14' in the other. The resistance of Norin 10/Brevor-14 is considered to be the best source of flag smut resistance in the wheats tested.

12. One Head of Bunt with Multiple Races. Collection 790 was a single head collection of Tilletia foetida obtained from Itana near Preston, Idaho, in 1963. When spores of this collection were used to inoculate the differential varieties, a new pathogenic type, race L-16, was identified in 1964. Reselection of spores from the differential variety 'Ridit' in 1964 apparently has screened out another pathogenic type which attacks the Ridit resistance. If pathogenicity of Ridit is confirmed, this collection will represent another new race of T. foetida (L-17) which can attack all of the major bunt resistant

factors except Hohenheimer. This reaction is similar to the common bunt, race D-3. It would be useful in screening varieties for new sources of bunt resistance.

13. Chemical Mutagen Yields Rust Resistant Forms. Derivatives of 'Little Club' wheat recurrently treated with ethylmethane sulfonate have shown a high frequency of seedling mutants following the third cycle of treatment. Three mutants resistant to stem rust have been recovered and one mutant shows resistance to races 111, 15B, and 32 to which it has been tested. Resistance in these mutants appear to be associated with a chlorophyll deficiency.

14. Rust Epidemics Fit Statistical Models. When the rate of leaf and stem rust development is continuous, prediction can be expressed in the form of linear regression. When the infection rate is discontinuous, a complex model, such as a polynomial, can be used.

Results of aerobiological studies in Kansas show that differences in leaf rust urediospore and Cladosporium sp. conidia content of the air exist during the morning, afternoon, and evening, and at various elevations within these periods. The highest concentration of airborne urediospores and conidia was in the afternoon at 1,000 feet. There was a distinct drop in spore numbers of both fungi at about 4,000 feet. Numbers of spores trapped during the morning and evening flights were consistently lower than those caught during the afternoon at 4,000 feet and below.

15. Nonspecific Reactions to Rust Show in Minnesota and Puerto Rico Studies. Varieties of wheat have measurable differences in the rate at which stem rust infection increases. This can be attributed to "non-specific resistance". Slow rates of increase can lead to a significant reduction of yield loss from stem rust. Spore counts essentially are as effective in measuring epidemics as actual pustule counts and they have the added advantage that more frequent counts can be made. This leads to considerable statistical leverage for analysis.

16. Spring Wheat Sources of Resistance to Stem Rust Hold Lead Over Pathogen. Analysis of stem rust collections showed that most of the rust comprised races to which the principal spring wheat varieties are resistant. The prevalence of races in 1966 was similar to that for 1965, and 15B-2 was the most common. Races 56, 17, 11-32, and 151 were present in declining order.

Seventeen sources of seedling resistance offer protection against the seven physiological races of wheat stem rust that account for over 90% of the isolates of wheat stem rust identified in the United States in 1965.

17. Rod Collectors of Spores More Efficient Than Slides. Comparisons were made between rod and slide samplers in an attempt to regain the history of past epidemics by finding if the two methods were comparable and if so, how much more efficient rod samplers were. In this experiment, results from rods

and slides were highly correlated, but the rods on the average trapped 4.0 times as many stem rust spores and 5.7 times as many leaf rust spores as did the vertically mounted microscope slides (cooperative with Plant Pest Control Division).

18. Rain Water Collectors Detect Rust Spores Early. Comparisons were made on the effectiveness of two methods in the detection of rust in the field. Spores were trapped on rods as early in the season as pustules were found in the field. In rain collections, rust was detected 8 to 10 days before it was detected in the field at all but one station north of Kansas-Nebraska border (cooperative with Plant Pest Control Division).

19. Ultrastructure Studies Show Host Response to Pathogen. In research supported by a grant to Duquesne University in Pittsburg, Pa., many observations have been made on the lomasomes. They seem to originate from the host protoplast and are thought to be a direct response of the host protoplast to the presence of the pathogen. However, they are not directly related to resistance or susceptibility. The lomasomes are thought to be involved in the alteration of the host cell wall which is known to occur in infection centers. They appear analagous with border bodies of various sorts that can be seen in green plants at sites of developing primary and secondary walls.

20. Pathogenic Potential of Rust Fungi in Europe and Near East Compared to USA. The results, which have been obtained through several PL 480 projects, fit into an overall picture of the rust situation in Europe. In central Europe, leaf rust is the most important wheat rust and the principal races are 77 and 57. The principal and epidemic races of Puccinia graminis tritici are characterized by avirulence corresponding to the Sr5 locus which is found in one of the differentials, 'Reliance'. On project E25-CR-3 in Spain, over a five-year period, no cultures were obtained with virulence corresponding to Sr11 (Lee). This was demonstrated in surveys, catch nurseries near barberry, and in crosses. Other work done in Europe, the Near East, and Egypt indicates that the gene for virulence to Sr11 does not exist in the population of the pathogen. Thus, any resistant varieties introduced from this general area should be tested with United States cultures carrying this gene for virulence. The intensive work under PL 480 project F4-CR-1 in Egypt, on race identification of the wheat stem rust fungi, demonstrates that virulence corresponding to the Sr11 gene does not occur in that country. Additional work on testing indicates possible importance of the Sr10 gene in enhancing the degree of protection against Puccinia graminis given by certain other genes. Genetic studies indicate that 'Giza 139' carries a gene identical or similar to that in Ill. 1 x² Chinese x Timopheevi. It is not clear if the Sr10 gene originates from T. timopheevi or not.

Work with leaf rust indicates that the pathogenic potential of Puccinia recondita in Egypt is distinctly different from that in the United States. For example, Lee is considered to be a resistant variety in Egypt.

Leaf rust is the most important wheat rust in Poland. The average annual loss is 3-5% for the country as a whole. The last serious epidemic of stem rust occurred in 1932 but there is a small annual loss in eastern and southern Poland where barberries are common. Stripe rust is of no importance. In race surveys Puccinia recondita races 12, 15, 21, 54, 55, 57, 58, 61, 76, 77, 84, 85, 94, 122, 156, 162, 166, and a new race were identified. Races 57 and 77 were the most prevalent during 1961-66. Puccinia graminis tritici races identified were 14, 17, 21, 27, and 40 of which 14 and 17 were most prevalent.

The idea that virulence to Sr11 does not occur in Europe and the Near East has been substantiated. This is a very important addition to our understanding of resistance in wheat to Puccinia graminis tritici because it adds emphasis to the concept that disease is not a character of the plant. The gradual development of this concept has and will continue to be a major contribution in the development of better wheat varieties.

21. Blackpoint Disease of Wheat Seed Varies Widely. In Texas 366 selections of wheat were examined for blackpoint. The range of infection varied from 0-87%. A high percentage of blackpoint was associated with certain locations and more disease was observed in seed from irrigated fields than from dry-land farms. Seeds with blackpoint yielded more than 20 different fungi when placed on agar. The number of fungi isolated varied with the part of the seed examined. The crease section yielded the greatest number. In North Dakota cooperative tests, Helminthosporium and Alternaria were associated with blackpoint, but there were only a few infections and black-point symptoms due to Alternaria.

C. Quality

1. Semi-Commercial Mill Complete Success. Use of a laboratory pilot experimental commercial mill composed of 2 Miag Multomats and a laboratory purifier, gave information on the milling characteristics of a wheat sample as small as 50 pounds, although 100 pounds was preferred. A minimum amount of warm-up time is necessary before the actual milling. Essentially identical results were obtained on split samples milled at different times.

Over 75 tests were performed to establish the best combination of rolls, sieve sizes, and stream combinations in a pilot test-milling unit. Due to limited time and available clothing for the sieves, it was not possible to settle on a final flow; however, a functional code was developed. For comparative purposes, 20 CQC 1965 crop samples of clean, dry wheat were milled on both the Pillsbury Pilot Mill and the Twin Miag Pilot Mill. The data obtained on the mills were similar. Six specific studies were performed to determine the effect of various factors on milling, including moisture (tempering), mill temperature, sample size, and reproducibility of results from which an improved flow sheet was developed.

2. Weather and Cookie Quality Related. At Wooster, Ohio, correlation analysis between cookie diameter on the one hand and various temperature and precipitation data on the other indicated that high average minimum daily temperature during winter dormancy was associated with improved mean cookie spread. The precipitation data were subdivided into wheat plant growth periods. A multiple correlation coefficient of 0.934 was obtained by including eight independent variables, most of which were temperature factors associated with growth periods before anthesis.

3. Cake and Cookie Quality Affected by Lubricants. Contamination of cookie doughs and cake batters with as little as 10 ppm quantities of materials containing silicone and its derivatives exerts a profound detrimental effect on the baked products. A possible source of contamination is the stopcock grease used to lubricate pipettes and burettes for dispensing ingredient solutions. Non-silicone materials had no effect on baking properties.

4. New Micro Sedimentation Test Separates Flour Types. Micro sedimentation data delineated flours quite naturally into three general types: Hard (bread) types, soft common types, and club types. A number of soft common types fell into the hard (bread) area, and thus were not clearly separated from them. All the soft club types fell into the lowest strength area. The delineation resulted in uncertain classification of 4% of the hard (bread) types which were grouped in with soft common types.

5. Small Kernels Contain More Lipids. Wheat samples from three hard red winter and three hard red spring varieties were separated into kernels of varying size. A twofold increase in kernel weight was accompanied by a small decrease in protein content and by a substantial decrease (on a percentage basis) in ash. Concentrations of free (petroleum-ether extractable) and of bound lipids (in water-saturated butanol following petroleum-ether) were higher in small kernels than in large ones. Total lipid contents per kernel depended primarily on kernel size.

6. Variable Effects of Pentosans (or allied materials) from Diverse Sources. The pentosans from hard red winter, hard red spring, soft red winter, and club wheat - but not durum - increased water absorption. The pentosans decreased dough development time and dough stability, when measured by a micro-Farinograph technique. Durum pentosans lowered Amylograph peak viscosity; pentosans from other flours increased or had no effect on peak viscosity. Added pentosans increased oxidation requirements. Loaf volumes were increased by adding pentosans from hard red winter and club flours, and were decreased by adding pentosans from soft red winter and durum flours.

7. Backcrossing Quickly Establishes Mixing Properties. Differences were noted in number of backcrosses necessary to recover the mixogram curve type of recurrent parent. When 'Tenmarq' was used as the recurrent parent, its mixogram curve type was obtained in BC^2 and BC^3 . When 'Chiefkan' was the

recurrent parent in combination with Tenmarq and Comanche, the mixogram curve type of Chiefkan was recovered with a single backcross. In the backcross where Comanche was the recurrent parent, three backcrosses were required to recover its mixogram curve type. When Chiefkan and Cheyenne were used as recurrent parents, in the cross between these cultivars, their respective mixogram curve types were recovered by the third backcross.

8. Dispersibility of Proteins Altered by Heat. The dispersibility of wheat flour proteins in 3M urea was found to be a sensitive parameter for evaluating the effects of heat during the drying of damp, preripec wheat, or for evaluating the effects of steam-conditioning of wheat on breadmaking potentialities of flours. Dispersibility of proteins decreased with length and severity of heat treatment, and paralleled the damage to some rheological properties and bread quality.

9. Lipids Hold Key to Many Responses. By isolating lipids and studying their behavior during certain treatments, flour properties and characteristics could be determined. Profound changes in rheological properties and breadmaking characteristics of the flours were accompanied by a small decrease in the ratio of nonpolar to polar lipids and by an increase in the phosphorus content of the fraction. Some changes in flour lipids from irradiated wheat were noticed during fractionation by TLC and during determination of infrared spectra.

Lipids fractions isolated from various flours indicated no varietal differences. Total free lipids containing a mixture of nonpolar and polar components (in a ratio of 3:1) decreased loaf volume and impaired crumb grain of bread baking from petroleum-ether-extracted flours; the deleterious effects were counteracted by polar lipids. The effects on bread depended on the levels and ratios of the nonpolar to polar lipids. Preliminary investigations were conducted on the effects that would be made on breadmaking by adding DEAE-cellulose-column-separated fractions. Fractions rich in galactosyl glycerides increased loaf volume the most.

10. Shortening and Lipid Interactions. By adding shortening to the original hard red winter wheat flours, loaf volume and crumb grain were improved substantially and consistently but when shortening was added to defatted flours crumb grain of bread was impaired. By adding shortening to the dough formula, loaf volumes of bread baked from defatted strong flours were decreased and those from defatted weak flours were increased. The shortening response of strong flours was completely restored by adding free lipids from any of the six flours tested. It was established by reconstitution techniques that the amount of free lipids required to give the original loaf volume was at least half the amount in the original flour. Refined corn oils that vary in iodine value could not replace the free flour lipids in reconstitution studies.

11. World Collection Being Screened for Lysine. A search for apparently new genetic sources of high lysine and protein in wheat is being made in a lysine screening project (Nebraska and AID cooperating). It is too early to predict whether genetic sources of high lysine have been or will be found, but the range looks promising. Analytical data for 700 samples were obtained.

Amino acid studies of the Nebraska high-protein lines are encouraging. The first nutritionally limiting amino acids do not appear to be adversely affected in higher protein lines.

12. Macaroni Quality Altered by Removal of Water Insolubles. Color development was related to the amount of water soluble material in cooperative studies in North Dakota. When all of these materials were removed the macaroni was light in color and soft in texture. Reconstituted semolina gave near-normal scores. When nine varieties of durum wheat were extracted with water and separated by centrifugation into soluble and insoluble fractions, various chemical studies revealed that the solubles could be separated into six major acidic protein fractions and five major basic protein fractions. Studies of molecular size revealed that a broad range was represented -- many times greater than the number of basic groups initially found.

D. Physiology and Culture

1. Varieties Differ in Translocation Efficiency of N. Nitrogen uptake followed dry weight increase very closely in a number of varieties observed in Nebraska. The weight of nitrogen per plot also increased in all varieties except NB631068 until June 23. Nitrogen uptake and dry weight decreased during June 23-30. Warrior took up the most nitrogen; 'Wichita' the least. 'Atlas 66' x Comanche (NB631068) absorbed the most nitrogen until June 2, but appeared to take up little if any nitrogen thereafter. The percentage of total plot nitrogen found in the grain of each variety during three stages of grain maturation was the lowest in Warrior before June 30 and nitrogen in 'Lancer' was also slightly lower on June 30. The data support earlier findings that neither Warrior nor Lancer have the capacity to translocate nitrogen to their grain as efficiently as Atlas 66 x Comanche or Comanche.

2. Nitrate Reductase Activity Related to Protein per Acre. Cooperative studies in Illinois showed a linear relation between seasonal input of reduced nitrogen per acre and grain protein per acre. Variety efficiency is under investigation.

3. Feeding Habits of Greenbug Help Detect Nature of Resistance in Wheat and Barley. Work with barley plants grown in a $^{14}\text{CO}_2$ atmosphere shows that greenbugs that feed on these plants during exposure to the $^{14}\text{CO}_2$ become highly radioactive. Non-radioactive greenbugs that feed on labeled plants also

become highly radioactive. When labeled greenbugs were used to infest "cold" barley plants, the sites of feeding, as indicated by necrotic areas, also became labeled with compounds containing ^{14}C . (cooperative with Entomology Research Division and Oklahoma)

4. Inhibitors, Inducers, Gibberellic Acids, Modify Growth. Inhibitors and inducers of growth were isolated from nonvernalized winter wheat and spring wheat. They were partially purified by column and thin-layer chromatography, and bioassayed by the coleoptile growth test and the heading time of spring wheat. A sensitive bioassay for gibberellic acid was developed which employed aleurone fragments of wheat seed coat. Alpha-amylase was produced in response to added gibberellic acid. The hydrolysis of starch showed a nearly linear relation to gibberellic acid levels over the range 10^{-4} to $1\text{ }\mu\text{g}$ gibberellic acid.

5. Tissue Culture of Wheat Yields Tilletia. The common bunt races T-1 and T-10 of Tilletia caries were recently isolated from infected wheat plants. Some of the isolates have produced teliospores in culture. The pathogenicity of these isolates remains to be tested.

6. Male Sterility Related to Vascular Deficiencies. Microsporogenesis was compared in anthers of fertile and cytoplasmic male sterile winter wheat. Tapetal cells formed less starch and persisted longer in male sterile anthers. Meiosis was normal, but little or no starch appeared in mature pollen. It is indicated that inadequate vascular development reduces solute transfer to the stamens of sterile plants.

7. Frost Hardiness and Crown Location Related. Severity of leaf tissue injury caused by the hard frost of October 20, 1965, at Pullman, Wash., was in close negative correlation with known winterhardiness of named varieties and with the length of tiller regrowth of the same varieties after crown freezing.

Preliminary experiments indicate that leaf tissue injury of pot-grown seedlings, in the 2- to 3-leaf stage, severely frosted in the freezer and this may be used as an index of the relative coldhardiness of the varieties involved.

Plantings made during the period from late June to August were not useful in determining the crown depth and second crown information. In many plants it was impossible to determine the location of the crown because its nodes had become separated by internode elongation. Correlation data indicate that depth of crown establishment, the number of second crowns, and the number of tillers per plant are varietal characteristics.

8. Decarboxylation of Indole Acetic Acid (IAA) in Rust Infected Wheat Plants. Temperature-induced resistance mechanisms become operative only after 3 days following inoculation. IAA decarboxylation rates for susceptible plants and controls were much the same for 2-3 days after infection,

but resistant plants thereafter showed a rise in decarboxylation to 8 times that of healthy controls.

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OAT AND BUCKWHEAT BREEDING, GENETICS, DISEASES,
QUALITY, AND PHYSIOLOGY
Crops Research Division, ARS

Problem. Within recent years there has been a decline of acreage planted to oats -- especially winter oats. This can be attributed in a large degree to the uncertainty of oat production because of the susceptibility of the crop to diseases and to weather damage. Disease-resistant varieties are in constant demand. There is little basic information on effects of the fungus and virus diseases on winter survival, yield, and quality, and the effects of environmental factors on disease development and damage. Even though barley yellow dwarf disease and soilborne mosaic greatly affect the productivity of oats, much remains to be learned about vectors, host ranges, pathogenic and vector specificity, physiology, and biochemistry of these viruses. If yield, quality, and balance of the amino acids and vitamins of oats were improved, the value of oats as livestock feed and human food would be increased. Until these desired characteristics are based on heritable traits and appropriate inheritance and breeding studies are made, oats as an agronomically desirable, disease resistant, and nutritious grain will not progress very fast.

Buckwheat is a minor crop and its improvement has been postponed. To make it profitable to produce this crop, the quality will have to be improved, and yield increased by better understanding of its actions in breeding processes. Disease resistance, grain quality, and adaptation of the plant to various environmental and cultural practices would help to make buckwheat more desirable for crop production.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term research program involving pathologists, geneticists, physiologists, and agronomists engaged in both basic and applied research in an attempt to solve the problems besetting the oat crop. The ultimate objective is to stabilize production, increase efficiency, and improve the quality of oat grain and forage wherever it is grown. Most of the work on the breeding, genetics, physiology, and diseases of oats is conducted in cooperation with State Agricultural Experiment Stations in Arizona, California, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Mississippi, Missouri, New York, Pennsylvania, South Dakota, Texas, Virginia, Washington, and Wisconsin; the Puerto Rico Agricultural Experiment Station; and at Beltsville, Md.

Extramural research is conducted at Michigan on breeding and genetics related to cereal leaf beetle and in Idaho on non cultivated species of oats.

Oat research is being conducted under three PL 480 projects, one in Colombia, S. A., on extremely virulent races of oat stem rust; a second in Israel on collecting and screening wild species of oats for resistance to virulent races of stem and crown rust; and a third in Israel on evolutionary studies of oat species.

Buckwheat breeding and genetics are limited to an industry-supported graduate student at University Park, Pa.

The Federal scientific effort devoted to research in this area totals 12.6 scientist man-years. For intramural, 5.7 is devoted to breeding and genetics, 5.9 to diseases, 0.3 to quality, and 0.5 to physiology.

At Michigan Agricultural Experiment Station there is support of 0.1 SMY on breeding and genetics related to cereal leaf beetle research pertaining to oats, and at Idaho 0.1 on seed production of noncultivated species of oats.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 27.5 scientist man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Improved Oat Varieties. 'Diana,' a spring oat, was released to plant breeders for germ plasm or commercial use. It was developed cooperatively by the Purdue Agricultural Experiment Station and ARS. Improved characteristics of Diana include, adult resistance to race 26⁴ of crown rust, stem rust resistance, good strength of straw, test weight, and yield of grain.

'Jaycee,' a spring oat, was developed cooperatively by the Illinois Agricultural Experiment Station and ARS. It is high yielding and possesses considerable field resistance to the barley yellow dwarf virus, especially under a heavy infection of barley yellow dwarf in Illinois in 1966. Jaycee is earlier maturing and shorter strawed than any variety currently grown in Illinois, with high test weights, early maturity, and lodging resistance due to straw strength and short straw. It is resistant to races 6, 7, 7A, and 8 of stem rust and races 203 and 216 of crown rust.

'Mesa' is an all-purpose grain and forage spring oat developed for use in the low altitude, irrigated areas of southern Arizona. It was released by the Arizona Agricultural Experiment Station and ARS. The origin of Mesa is unique in that it was selected from a cross of Kanota and the wild oat, Avena fatua. Mesa has performed well in the production of grain, pasture

forage, and hay. It has good standing ability and is intermediate in height and maturity. Mesa has considerable tolerance to barley yellow dwarf. It was not tested for smuts and rusts since they are not usually a serious problem in southern Arizona.

2. Improved Buckwheat Varieties. 'Pennquad', a tetraploid buckwheat variety, was developed cooperatively by the Pennsylvania Agricultural Experiment Station and ARS. It is the first buckwheat variety to be released by an experiment station in this country and had double the normal number of chromosomes. Yield, maturity, and standing ability of Pennquad were evaluated for 4 years at University Park, Pa. In separate tests at various places in Pennsylvania, Pennquad substantially out-yielded 'Tokyo', the top variety now in use, and showed an average of only 5% lodging compared to 35% for Tokyo. It is adapted to production in Pennsylvania and areas with similar climatic conditions. It may be grown for either grain or green manure. Pennquad should help stabilize production from a currently small buckwheat acreage.

3. A System of Genetic Nomenclature for Oats. A standardized system of nomenclature for 193 genes or loci governing characters in oats has been developed and published. Prior to this publication, there have been no rules and only few suggestions to guide investigators in this field.

4. Isogenic Lines Used to Measure Loss from Crown Rust. Resistant and susceptible isogenic lines of oats were used in cooperation with the Texas Agricultural Experiment Station to measure reduction in yield and test weight caused by crown rust in Texas. Reduction in yield ranged from 8 to 56%. Test weights of susceptible lines were significantly less than for resistant ones.

5. Feral Oat Collection. Approximately 700 feral oats collected from roadsides and fields in Texas and Mexico have been evaluated in Texas for agronomic, morphologic, and pathologic characters. A wide range of morphologic characters were observed. Resistance to races 276 and 294 of crown rust was relatively common. Various combinations of resistance to stem rust races 2, 6, 7, 7A, 8, and 10A were found. Cold tolerance and resistance to Victoria blight were also observed.

6. World Oat Collection. The USDA World Oat Collection had an inventory of 8,233 entries at the close of 1966. There are 6,309 entries with cereal investigation (C.I.) numbers and 1,924 entries with plant introduction (P.I.) numbers. During the year, 39 varieties of Avena sativa were received from foreign sources. In the Avena species collection 767 samples of A. sterilis from Israel were accessioned. Eight States and 2 foreign countries contributed 37 varieties of oats that are either named or selections that have been declared open stock.

7. Natural Selection for Cold Resistance in Oats. The effect of 3 consecutive years of severe natural selection pressure on the cold resistance of 23 different winter oat bulk F_3 , F_4 , and F_5 generations was determined. Controlled freezing tests with remnant seed from these generations, and the F_2 which was not subjected to winter stress, demonstrated that natural selection caused a significant increase in cold resistance each year. Populations with a low initial survival value had the greatest potential for change.

8. Inheritance of Symptom Expression and Avirulence in Race Hybrids of *Ustilago avenae*. The characteristically different symptoms produced by races 2 and 7 of *Ustilago avenae* on 'Camas' are heritable in single factor pair ratios independently of virulence. The powdery sorus of race 2 was recessive to the blast symptom of race 7, whereas the higher virulence level of the former race is sometimes recessive and sometimes dominant to the lower virulence level of race 7.

9. Inheritance of Spontaneous Mutations of the Victoria Locus. Susceptibility to *Helminthosporium victoriae* in oats is controlled by a single dominant factor. Partially susceptible and partially resistance mutants, isolated from susceptible varieties, were crossed with the susceptible parent. Reaction of F_1 plants were intermediate to both parents. F_2 segregation indicated that the Victoria locus is composed of two or more alleles which exhibit semidominance.

10. High Protein Oats. Sources of unusually high protein content have been found in the wild hexaploid *Avena sterilis* species being obtained from Israel. A few lines of *A. sterilis* possess a combination of large groats, 30% protein, and outstanding resistance to crown rust. Resistance to stem rust, soilborne mosaic, barley yellow dwarf virus, and other diseases has also been observed. Studies are being conducted to determine the inheritance of protein content and other characters in *A. sterilis*, and breeding programs have been initiated to incorporate these characters into desirable agronomic types.

11. Possible Tetraploid Contributor to Hexaploid Oats. *Avena ventricosa*, a supposedly rare, wild diploid oat species, was found and is widely distributed in the Mediterranean Region. Only two collections of this species had been reported previously, one from Algeria and another from Baku. This species is of special interest since it is thought to have played an important part in the evolution of cultivated hexaploid oats.

12. Monosomics of Hexaploid Oats. Monosomics A-F, inclusive, have been isolated and genetically identified in Iowa. The monosomic-chromosome numbers are as follows: A-17, B-16, C-14, D-7, E-20, and F-19. Monosomic-chromosome numbers 17-2, 31-3, 34-21, and 39-13 have been genetically identified. These will be assigned letters after consultation with other

oat cytogeneticists. The frequency of nullisomics from monosomics C and F in Cherokee oats appears to be determined by the genotype. For example, the frequency was greatly increased when monosomics C and F were crossed with unrelated varieties.

13. A tetraploid Avena sterilis. A Canadian-Wales collection of A. sterilis possessing unusually high protein, large groats, and outstanding crown rust resistance has been identified as a tetraploid. A. sterilis previously had been identified only as a hexaploid. The tetraploid condition will increase the difficulty of utilizing the outstanding characteristics of this collection, especially for those characters controlled by several genes. Crosses and backcrosses have been made for the purpose of transferring the desirable characteristics of the tetraploid to a hexaploid type with good agronomic characters.

B. Diseases

1. Effect of Radiation on Spore Germination and Virulence in Ustilago avenae. X-ray treatments at dosages ranging from 50 to 300 kr reduced spore viability and induced abnormal spore germination but failed to alter pathogenicity in pedigree homozygous lines of U. avenae.

2. A New and Virulent Race of Oat Stem Rust. Extremely virulent race 6AFH was first collected near barberries in the Northeastern region and has now become established in the North-South movement in the Mississippi Valley. The only cultivated oat genotype that expressed adult resistance to 6AFH was C.I. 3034. Several selections of the hexaploid A. sterilis have been resistant in the seedling and juvenile stage but exhibited a susceptible culm reaction after reaching the heading stage.

3. Tolerance of Oat Varieties to Crown Rust. The relative tolerance of 24 varieties of oats to three races of crown rust was determined in Iowa by using split plots with 1/2 rusted and the other half protected from rust. Cherokee and several other varieties with susceptible reactions were significantly more tolerant than Clinton and Benton, as measured by kernel weight.

4. Relation of Date of Planting of Oats to Crown Rust Damage. Varieties of oats with differences in tolerance to crown rust were compared under rusted and nonrusted conditions at four dates of planting in Iowa. In the presence of rust, Cherokee, Andrew, and Clinton reflected regular declines in yields and kernel weights with progressive delays in planting date. Cherokee and Andrew showed no differences in relative rust damage at the first or second dates. Cherokee was relatively less damaged than Andrew at the fourth planting date. Clinton showed more damage than Cherokee at all four dates, with an indication of greater relative difference at the later dates.

5. Pathogenicity of Isolates of Crown Rust Collected in 1961-65. Over 3,000 isolates of crown rust collected from oats and more than 1,000 from buckthorn were tested for pathogenicity on key differential oat varieties from 1961-65. Of the isolates from oats, race group 290, which is virulent on Bond and Landhafer, made up 44% of the total; race group 216, virulent to Bond and Victoria, made up 34%; race group 264, virulent to most sources of resistance, made up 7%. Of the isolates originating as aecia from buckthorn, 65% were race group 290; 21% race group 202; 9% race group 216; and 2% race group 264.
6. Transmission of Barley Yellow Dwarf Virus by Clones of Several Aphid Species. No differences in ability to transmit four strains of barley yellow dwarf virus (BYDV) were found when New York clones of Macrosiphum avenae, Schizaphis graminum, and Rhopalosiphum maidis were compared with clones from the same species from Kansas. A Kansas clone, R. padi, however, regularly transmitted one strain of BYDV that was rarely transmitted in parallel tests by the New York clone of R. padi. Some minor morphological differences were observed between the Kansas and New York clones of R. padi.
7. Summer Hosts of Barley Yellow Dwarf Virus. Ten weed species suspected of being natural summer hosts for barley yellow dwarf virus were inoculated with the apple grain aphid strain of the virus in Mississippi. Recovery of BYDV was accomplished from 6 of the 10 species tested. Five, were reported as hosts for the first time. They are: Brachiaria platyphylla, Cyperus rotundus, Eleusine indica, Panicum ramosum, and Phalaris angusta.
8. Seedling Blight of Early Planted Oats in Florida. Pythium aphanidermatum was demonstrated for the first time to be the causal agent for a seedling blight causing severe damage on early plantings of oats, rye, and wheat in Florida. Losses in some cases have been estimated as high as 75% of the expected stand. Three isolates of the fungus obtained from different hosts were similar in pathogenicity.
9. Reactions of Oat Varieties to Loose and Covered Smut. Ten smut differentials and 96 agronomic varieties were tested with 23 races of loose and covered smut. Fifty-three varieties were immune, highly resistant, or resistant to all races with which they were tested. Thirty of these were free from infection to all races tested, with 19 being apparently immune to the full set of 23 races. Only one variety was susceptible to all 23 races.
10. Phytokinins Enhance the Effect of Victorin. Victorin, the pathotoxin produced by Helminthosporium victoriae, causes permeability changes and wilting in susceptible oat varieties, but has no effect on resistant varieties. Excised leaves of susceptible oats treated with phytokinins and victorin wilted more rapidly than those treated with only victorin. When excised leaves were treated with phytokinins and allowed to take up the same quantity of victorin as leaves not treated with phytokinins, there

was no difference in the time or degree of wilting. It appears that phyto-kinins do not increase the toxicity of victorin but enhance its effect by increasing the uptake of this toxin.

11. Race 3D* of Oat Stem Rust in Colombia, S. A. Subrace 3D*, which is important because it attacks the hitherto recently developed resistant oat variety ICA-BACATA, made up 16.6% of the oat stem rust collections in Colombia in 1966.

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RICE BREEDING AND GENETICS, DISEASES, QUALITY, AND CULTURE
Crops Research Division, ARS

Problem. Rice in the United States is grown under several environments and cultural methods and on a wide range of soil types. Varieties of many types are required to meet the demands of the consumers and processors. Rice research workers face a variety of problems in respect to physiological characteristics and exposure to disease and insect pests because of the different environmental situations where rice is grown. The improvement in rotation systems, the increased use of nitrogen fertilizer, and better weed control methods have made necessary a modification of breeding objectives. Varieties are required that have seedling vigor under adverse conditions such as low temperature of soil or water so that good stands can be established in a short time, so that weed competition can be minimized. Herbicides are available for the control of many of the serious grasses and broadleaf weeds in rice. This enables the growing of short season varieties because weed competition during the vegetative stage can be eliminated. High rates of N fertilizer increases the susceptibility of rice to blast, kernel smut, and lodging. Thus, the breeding of varieties resistant to these diseases and to lodging is of increasing importance. The nutritive value of rice also must be improved by increase of quantity and quality of protein. The exacting requirements of consumers require that all breeding lines be evaluated for milling, cooking, and processing characteristics.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving plant breeders, geneticists, plant pathologists, and chemists who are engaged in basic and applied research to develop improved varieties and better methods for controlling diseases. This research is designed to stabilize production, increase its efficiency, and improve the quality of rice. Rice research is conducted at Beltsville, Md.; and in cooperation with State Agricultural Experiment Stations at Stuttgart, Ark.; Biggs, Calif.; Baton Rouge and Crowley, La.; and Beaumont, Tex. The work at Biggs, Calif., is also in cooperation with the California Cooperative Rice Research Foundation, Inc.; and that at Beaumont, Tex., with the Texas Rice Improvement Association, and other private enterprises interested in rice quality.

Rice research also is conducted under six PL 480 projects with (1) the Central Rice Research Institute, Cuttack, India, on the nature and variability of resistance of rice to the blast fungus and in physiological specialization in the causal organism; (2) the Institute of Botany, Academia Sinica, Taipei, Taiwan, on cytogenetics of rice and its related species; (3) the Taiwan Agricultural Research Institute, Taipei, on physiological races of rice blast fungus; (4) the Taiwan Provincial Chung-Hsing University, Taichung, on genetic studies of mutations induced by radiation; (5) the Central Rice Research Institute, Cuttack, India, on chemical mutagenesis of

rices; and (6) the India Agricultural Research Institute, New Delhi, India, on the collection and study of cultivated rices in northeast India and the assessment of the possibility for mutational rectification of undesirable traits prior to the use of wild rice in breeding.

The Federal intramural scientific effort devoted to research in this area totals 8.3 scientist man-years. This number includes 4.6 devoted to breeding and genetics; 2.0 to diseases; 1.3 to quality; and 0.4 to culture.

There is no extramural program on rice in this area.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 12.6 scientist man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Improved Rice Varieties. 'Starbonnet,' developed cooperatively by the Arkansas Agricultural Experiment Station and ARS, is a high-yielding, long-grain variety with short, stiff straw. It is similar in grain type to 'Bluebonnet 50' but it matures about eight days earlier, is higher yielding and lodges less than this variety which it is expected to replace. Enough seed was released from the Arkansas Rice Branch Experiment Station to seed about 6,000 acres.
2. World Rice Collection. About 845 additional varieties from the World Collection of Rice Varieties were grown at Stuttgart, Ark. and Beaumont, Tex. They included about 80 new introductions and about 745 varieties not previously classified. These varieties were classified for certain plant characteristics and for physiochemical characteristics of the grain. About 185 new introductions were received and grown under quarantine at Beltsville, Md.
3. Alien Additional Line From Interspecific Hybrid. In research in Taiwan under a PL 480 grant, a triploid (AAE) from the cross Oryza sativa x O. australiensis backcrossed to O. sativa gave a plant with the O. sativa genome plus one chromosome from O. australiensis. The spikelet of this alien addition line was quite different than the spikelet of the O. sativa parent.
4. Productivity in Relation to Grain Type. Farmers have observed that medium-grain rice varieties usually yield more than long-grain varieties with a similar length of growing period. To check this observation, eight pairs of medium- and long-grain varieties were compared in a yield experiment for

two years in Louisiana. The 2-year average yield of the medium-grain varieties exceeded that of the long-grain by about 500 pounds per acre. There were exceptions, however, as 'Dawn' a long-grain variety yielded more than 'Nato,' a medium-grain variety, in both years.

B. Diseases

1. Pathogenic Races of the Blast Fungus in the Western Hemisphere. Studies at Beaumont, Tex. and Beltsville, Md. have shown that 13 pathogenic races of Piricularia oryzae occur in the Western Hemisphere. These 13 races are in 6 of the International race groups. Resistance to each of the 13 races is available in rice varieties in our collection. 'Zenith' is resistant to all except those in the IB group. 'Saturn' and Dawn are resistant to most of the known races in this hemisphere. These varieties and others are being used in breeding programs to develop resistant varieties.
2. International Blast Nursery. A nursery of 120 entries was grown at about 30 locations in the United States and 10 other countries in the Western Hemisphere. The varieties in this nursery include the International differential varieties, the United States commercial varieties, a few breeding lines from each rice-producing State and a few new introductions.
3. Rice Seedling Diseases. Research in Louisiana on the control of seed rot and seedling blight shows that some fungicides now available commercially are superior to some of the seed treatment chemicals commonly used. Thiram is one of these superior chemicals now registered for use on rice seed.

C. Quality

1. Method to Evaluate Parboil-canning Stability of Rice. Rice varieties vary widely in their reaction to the processing method used in making canned soups. A laboratory method has been developed to evaluate varieties and breeding lines to determine their canning stability. It consists of parboiling and simulating canning treatment of small (5 to 15 gm) samples, measuring the loss of solids, and scoring for kernel splitting and fraying. This method serves not only to evaluate the canning stability of rice varieties but also to rate their cooking characteristics. Varieties suitable for canning are dry and flaky when cooked in the usual manner for table rice.

D. Culture

1. Midseason Nitrogen Application on Short-season Rice. Through research on rice in Arkansas it has been demonstrated that midseason top dressing of nitrogen (N) should be delayed until the longest internode of about half the plants are 1 to 1 1/2 inches long. When the N fertilizer was applied at this time, the mature plants were shorter, there was less lodging and the yields were higher than when the fertilizer was applied one to three weeks earlier.

2. Influence of Seeding Date and Rate and Amount of N on Yield of Two Rice Varieties. The very short-season rice varieties, 'Bluebelle' and 'Belle Patna,' were sown at three dates at 45, 90, and 135 pounds of seed per acre and fertilized at 80, 120, and 160 pounds of N per acre. Highest yields were obtained for both varieties from the late seeding and both varieties responded to increased amounts of N. Response to seeding rate varied according to N rate.

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ALFALFA BREEDING, GENETICS, DISEASES, PHYSIOLOGY AND BIOCHEMISTRY
Crops Research Division, ARS

Problem: Alfalfa is grown in the United States under a wide range of environmental conditions. Climatic and pest hazards subject the crop to great fluctuations in yield and quality. Spread of the alfalfa weevil seriously threatens most of the alfalfa acreage in the United States. Varieties resistant to these and other pests are urgently needed. Verticillium wilt and other diseases continue to be potential threats. Substantial increase in basic and applied research is needed to stabilize production and to cope with presently recognized hazards. Some problems are not readily solved by breeding, and their solution depends on management or other measures. Practical solutions rely on a continuing program of basic research.

USDA AND COOPERATIVE PROGRAM

The research program includes: Basic breeding and genetic studies; breeding for resistance to alfalfa weevil, potato leafhopper, spotted alfalfa aphid, pea aphid, bacterial wilt, common leafspot, and Leptosphaerulina leafspot; basic studies on pathogens causing diseases; breeding to improve forage quality; and cultural and physiological studies on management, diseases, and temperature stress. Research is conducted at Beltsville, Md., and at University Park, Pa., Raleigh, N.C., St. Paul, Minn., Brookings, S.D., Lincoln, Nebr., Manhattan, Kans., Logan, Utah, Reno, Nev., and Stoneville, Miss., in cooperation with the State Agricultural Experiment Stations. Most entomological research is in cooperation with the Entomology Research Division.

Four studies are being conducted under cooperative agreements and contracts - one at Reno, Nev., on mechanisms of resistance to pea aphids and spotted alfalfa aphids; two at Raleigh, N.C., on biosynthesis of coumestrol and mechanisms of resistance to stem nematodes; and one at the Research Triangle Park, N.C., on characterization of saponins.

There is a P.L. 480 contract at Perugia, Italy, to develop lines of alfalfa resistant to Verticillium wilt.

The Federal scientific effort devoted to research in this area totals 13.5 scientist man-years. Of this number, 7.9 are devoted to breeding and genetics, 2.7 to diseases, 2.1 to physiology and biochemistry, and 0.8 to quality and variety evaluation.

Extramural research includes 2.4 scientist man-years of which 0.8 is devoted to breeding and genetics, 0.5 to diseases, and 1.1 to physiology and biochemistry.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 43.0 scientist man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Multiple-pest resistant alfalfas released. 'Dawson' - a variety developed in cooperation with the Nebraska Agricultural Experiment Station is resistant to pea aphids, spotted alfalfa aphids and bacterial wilt. MSA-W4 and MSB-W4 are unrelated broad-based germ plasm pools developed by recurrent selection for resistance to potato leafhopper yellowing, bacterial wilt, rust and general adaptability. MSA-A3 and MSB-A3 are unrelated broad-based germ plasm pools developed by recurrent selection for resistance to spotted alfalfa aphids, leafhopper yellowing, rust and general adaptability. The germ plasm pools were developed at Beltsville, Md., Raleigh, N.C., and University Park, Pa., and released to plant breeders for use as breeding stocks.

2. Progress made in developing weevil resistant alfalfa. At Beltsville, Md., more than a million plants have been evaluated in two years in a concentrated program to isolate and intensify resistance to larval and adult forms of the insect and to combine resistance with good agronomic characteristics. Selection is being practiced within populations, each suitable for different parts of the weevil-infested area. Differences among 405 plant introductions of winterhardy alfalfas for weevil larval damage at each of three locations (Beltsville, Md., Raleigh, N.C., and University Park, Pa.) were small but highly significant. Significant genotype x environment interactions were also observed, which probably resulted from effects of day length and temperature on plant growth, plant morphology, and insect behavior. In North Carolina, significant correlation coefficients among larval damage, fall growth, and spring growth indicated a relationship between low forage productivity and resistance. Also, plants with thin stems were less preferred for oviposition. These relationships between plant growth characteristics and larval damage may confound field testing for antibiosis, and require laboratory evaluation for resolution.

3. Mass seedling screening for resistance to insect and disease pests. At Manhattan, Kans., the reaction of alfalfa strains to potato leafhopper could be determined in the seedling stage; seedling selection for resistance to tarnished plant bug also appeared promising. Mass screening of seedlings for resistance to spotted alfalfa aphids and pea aphids was continued at Manhattan, and Reno, Nev., and for resistance to alfalfa weevil and bacterial wilt at Beltsville, Md.

4. Resistance to Verticillium wilt. Two cycles of selection for resistance have been completed in Italy under a P.L. 480 grant. Progress from selection is being determined.

5. Reducing saponin content of alfalfa. At Logan, Utah, one cycle of selection markedly reduced saponin content. Estimates of heritability were 80% and higher. Research in cooperation with nutritionists gave additional impetus to the need for reducing saponin content of alfalfa to improve feeding value.

6. Basic genetic studies to increase effectiveness of selection procedures for improving alfalfa. a. The second cycle of selection to determine the relative effectiveness of tandem, independent culling levels, sum of ranks, and index methods of selection was completed at University Park, Pa. b. More than 30 lines in each of two germ plasm pools were carried to the S_3 generation in a study to determine the effects of inbreeding on hybrid and synthetic performance in alfalfa. c. At St. Paul, Minn., self-fertility of 16 alfalfa clones increased with temperature by 8% at 70° F, 15% at 85°, 45% at 95° and 71% at 100°. Minnesota clone 559, which normally has a selfed-pod set of approximately 4%, increased to 54% selfed-pod set at 100° F. This might explain inconsistencies observed in field and laboratory ratings for degree of self-fertility. d. An investigation into cytoplasmic male sterility in alfalfa was initiated at St. Paul, Minn. e. At Raleigh, N.C., seven non-inbred clones and their S_1 progenies were intercrossed according to a plan to test the effects of seven levels of inbreeding on fertility. Seed set was reduced drastically by inbreeding. The most drastic effects of inbreeding occurred in the zygote (after fertilization). f. At Reno, Nev., clone crosses gave consistently higher yields than S_1 crosses. g. A technical bulletin describing gene markers in alfalfa was completed at Beltsville, Md., and made available to alfalfa workers.

B. Diseases

1. Biosynthesis of disease-induced coumestrol in alfalfa. In extramural research at Raleigh, N.C., inoculation of DuPuits with different isolates of Ascochyta imperfecta produced slightly different levels of coumestrol. The time course of coumestrol accumulation after inoculation with A. imperfecta closely approximated the growth curve of a microorganism in culture suggesting that induction of coumestrol synthesis may continue only as long as the pathogen is undergoing replication. Coumestrol content was slightly increased if pathogen-inoculated shoots were fed cinnamic acid, suggesting that cinnamate may be a precursor of pathogen-induced coumestrol.

2. Fungicides. At University Park, Pa., 2, 3-dihydro-5-carboxanilido-6-methyl-1, 4, oxathiin was found to be fungistatic to isolates of Rhizoctonia and Pythium. No inhibition of Fusarium oxysporum, Phoma sp. or Sclerotinia sp. was detected.

3. Phytotoxic substances associated with disease infection. A phytotoxic substance produced by Myrothecium spp. was demonstrated at University Park, Pa. Its properties are being determined.

4. Nature of resistance to *Ditylenchus dipsaci*. In extramural research at Raleigh, N.C., resistance appears to be related to the capacity of resistant varieties to take up and incorporate calcium and other divalent cations more readily than susceptible varieties. This greater incorporation of divalent cations produces a higher proportion of water insoluble pectic substances which are more resistant to pectolytic enzyme attack. Resistance does not appear to be based upon physical barriers to penetration or to the production of nematotoxic substances.

5. Heat treatment appears promising in eliminating alfalfa mosaic virus. Nine alfalfa plants infected with several alfalfa mosaic virus isolates were subjected to continuous temperature of 35 - 36 C at St. Paul, Minn. Cuttings from the plants were periodically tested for AMV infection by assaying on Bountiful bean. No recurrence of virus infection has been detected in 113 of these plants varying in age from 2 to 10 months.

C. Physiology and Biochemistry

1. Resistance to diseases and aphids reduces accumulation of coumestrol in alfalfa. Research at Brookings, S.D., University Park, Pa., Raleigh, N.C., and Beltsville, Md., demonstrated that selection for resistance to common leafspot and rust reduced accumulation of coumestrol in alfalfa resulting from disease infection. Coumestrol content was negatively correlated with spotted and pea aphid resistance. Selection for resistance can be expected to reduce the accumulation of coumestrol in alfalfa when infested with aphids.

2. Accumulation of flavones and coumestans associated with disease infection in alfalfa. Research conducted at Brookings, S.D., University Park, Pa., and Beltsville, Md., in cooperation with the Western Utilization Research and Development Division showed that infection of alfalfa by common leafspot, *Pseudopeziza medicaginis*, caused an increase in flavones and coumestans, in addition to the estrogen coumestrol. The level of increase was positively correlated with the host's susceptibility to disease. These compounds continued to increase in infected plants for at least 18 days after inoculation. Studies of alfalfa infected with rust (*Uromyces striatus*) gave similar results. Rust urediospores have a high coumestrol content and loss of these spores from large lesions on highly susceptible plants made assays difficult.

3. Coumestrol associated with physiogenic spotting in *Medicago littoralis*. At Brookings, S.D., where foliage was kept free from disease and insect pests in a growth chamber, coumestrol was found in large quantities in the leaves of *M. littoralis* in contrast to less than 1 ppm in disease-free leaves of *M. sativa*. The highest concentrations, exceeding 1,000 ppm, were found in *M. littoralis* leaves that had turned brown and dried. The concentration of coumestrol in green leaves of *M. littoralis* was positively associated with the number of brown, necrotic spots which developed, and with plant age. No organism could be found associated with these spots. This condition has been described as "physiogenic" spotting.

4. Nature of resistance to pea aphid and spotted alfalfa aphid. In extramural research at Reno, Nev., an artificial diet for the pea aphid was developed. It may serve for testing additives, such as extracts from resistant or susceptible alfalfa clones.

5. Three vs four cuttings in Nevada. The 3-year yield data on the 95 polycrosses and five varieties, in which three and four cutting systems were imposed, indicated that genotype x cutting interaction was not significant in this material. The polycrosses maintained their relative rank under both the 3- and 4-cut systems where differences due to cutting system were highly significant. Good stands were still maintained in the 4-cut system.

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CLOVER AND OTHER LEGUMES BREEDING AND GENETICS, DISEASES,
QUALITY AND VARIETY EVALUATION, AND PHYSIOLOGY AND BIOCHEMISTRY
Crops Research Division, ARS

Problem. Clover and other legume species for hay, pasture, silage, soil conservation, or multiple uses include at least 50 species of regional or national importance. Those of major importance include red clover, white clover, crimson clover, sweetclover, birdsfoot trefoil, lespedeza, lupines, and crownvetch. These species provide a legume or legume component in situations varying from most intensive agriculture to road bank stabilization; especially needed are disease and insect resistant varieties of these many species, each variety adapted to a specific use and to a specific environment. Adaptation of existing ecotypes must be determined; information on biosystematics of many genera must be obtained to guide critically needed research on interspecific and intergeneric hybridization; disease and insect resistance must be incorporated into new varieties; and basic information on breeding methods for the species involved is prerequisite for most efficient plant improvement.

USDA AND COOPERATIVE PROGRAM

The Department has a long-time basic and applied research program under way largely in cooperation with State Agricultural Experiment Stations. Research involves breeding, pathological, or physiological studies on red clover at Madison, Wis., University Park, Pa., and Lexington, Ky.; sweetclover at Lincoln, Nebr.; white clover at Clemson, S. C.; crimson clover and other winter-annual clovers at State College and Stoneville, Miss.; other perennial clovers at Ft. Collins, Colo.; birdsfoot trefoil at Ithaca, N. Y., Columbia, Mo., Blacksburg, Va., Stoneville, Miss., and Tifton, Ga.; lupines and tick clover at Tifton, Ga.; lespedeza at Raleigh, N. C., and crownvetch at Raleigh, N. C., Columbia, Mo., and Blacksburg, Va. In addition to the cooperative program, basic and applied research involving breeding and/or disease investigations are under way on red clover, birdsfoot trefoil, and crownvetch at Beltsville, Md. Most entomological research is in cooperation with the Entomology Research Division.

The second year of a 3-year contract on nature of resistance to sweetclover weevil, with the University of Nebraska and cooperative with Entomology Research Division, was completed.

Contracts with appropriate research departments in foreign countries, supported in part by PL 480 funds, involve research on: (1) Metabolism of alkaloids in legumes and their physiological role, Poland; (2) Forms of nitrogen in legumes, Poland; (3) Collection and evaluation of native and introduced legumes, Brazil; and (4) Population studies and selection in Berseem clover and the closely related taxa, Israel.

The Federal scientific effort devoted to this research totals approximately 16.2 scientist man-years, with 10.5 devoted to breeding and genetics, 2.6 to diseases, 1.0 to quality and variety evaluation, and 2.1 to physiology and biochemistry.

The Extramural Program consists of approximately 0.4 scientist man-years in physiology and biochemistry.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 40.0 scientist man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Red clover. Selection for resistance to powdery mildew, northern antracnose, *Cercospora* leaf spot, and a complex of viruses was continued at Madison, Wis. A population containing only three sterility (S) alleles and the gene for white flower was increased at Madison, preparatory to S allele mutation studies. World ecotypes did not differ for extent of internal breakdown (IB) when evaluated at Beltsville; IB was highly correlated with diameter of crown.

2. Alsike clover. Four generations of selfing and three generations of sib-mating of tetraploid alsike clover at Fort Collins, Colo., produced deleterious effects on persistence, vigor, and height of plants. Vigor of open-pollination progeny of self-compatible plants was less than that of the 'Tetra' variety from which self-compatible plants were derived. Selection for persistence in alsike clover was effective.

3. Crimson clover. Breeding for high temperature dormancy, to delay germination and improve seedling establishment in late summer, was conducted at State College, Miss. Selection for non-shattering of seed appears relatively ineffective. F_2 data for six qualitative characters indicate each is determined by a single gene. Crosses among the best inbred (S_6) lines appear especially desirable as a method of breeding the species. Interspecific hybridizations involving crimson and closely related species were initiated.

4. White clover. Interspecific hybridizations at the tetraploid level were made at Clemson, S. C., among *Trifolium repens*, *T. nigrescens*, and *T. occidentale*, and between *T. hybridum* and *T. occidentale*. Cross-compatibility between species was influenced by plant accession. Tolerance to nematodes of selected clones was attributed mostly to general combining ability; 15 of 36 clonal single-crosses inoculated with

nematodes in the spring exhibited improved plant stands the following fall.

5. Sweetclover. At Lincoln, Nebr., a single, F_1 plant of the inter-specific cross Melilotus sulcata x M. infesta was grown to maturity and crossed to 15 other species of Melilotus; only the cross to M. segetalis was fertile and the two hybrids obtained died soon after germination. Seed set in intra-specific crosses of M. infesta was increased from 4 to 30 percent by delaying pollination 3 days after emasculation of the flower. Cooperative with the Entomology Research Division, selection and breeding M. officinalis for leafhopper resistance was initiated among available low-coumarin, aphid resistant, and otherwise agronomically desirable plant materials. Other cooperative research supports the hypothesis that complementary genes are involved in resistance to aphids. A potential pest of sweetclover, the sweetclover root borer, Walshia miscecolorella (Chambers), was found for the first time. Other studies indicate that phenylalanine ammonia-lyase activity in leaves is not primarily controlled by the Cu/cu alleles but may be influenced by them; that an enzyme catalyzes the addition of a glucose molecule to o-coumaric acid in cell-free extracts; and that extracts of Cucu and cucu seeds contain trigonelline in similar quantities. Also, morphological mutants have been obtained from a small, annual, autogamous strain of M. alba being utilized in mutation studies for new o-hydroxycinnamic acid mutants; ethylmethane sulfonate appears to be the most effective mutagenic treatment.

6. Berseem clover. PL 480 research in Israel determined mode of pollination of wild species closely related to Berseem clover, obtained inter-specific hybrids among some of the species concerned, and evaluated the species for morphological and agronomic characters. Diethyl sulfate mutations were obtained in Berseem clover.

7. Birdsfoot trefoil. Twenty-three new synthetic strains of trefoil have been developed and are being evaluated regionally. These include 15 synthetics from Ithaca, N. Y., 6 from Blacksburg, Va., and 2 from Columbia, Mo. A number of the strains appear superior to present varieties either in yield, seedling vigor, or resistance to root rots. Birdsfoot trefoil continues to show resistance to the alfalfa weevil. Progenies of desirable domestic clones of trefoil have generally been superior to progenies of crosses and backcrosses of domestic clones with non-hardy South American varieties.

At Ithaca, N. Y., fourth recurrent selection cycle plants averaged 80% more tolerance to 2, 4-D than Viking. "Recurrent selection" as compared to "progeny test" has been more effective in obtaining Syn 1 populations tolerant to 2,4-D. At Ithaca, N. Y., progenies of recombinations of specific inbred S_5 and S_6 plants have resulted in strains yielding 50 to 70% more than Viking. In the same program efforts are being made to

secure cytoplasmic male sterile plants. The backcross progenies of six interspecific crosses backcrossed to L. corniculatus five times were generally higher in pollen fertility in the 5th backcross than in the 4th. Plants having much pollen abortion do not show abnormal meiosis of chromosome irregularities.

General and specific combining ability for yield, vigor, flowering date, disease, and survival were determined in a 4-clone diallel cross at Blacksburg, Va. There were significant differences among crosses for flowering, vigor, disease score, and yield. General combining ability was present for flowering date, 2nd cutting 1965, 1st and 2nd cuts and total yield 1966. Specific combining ability was revealed for flowering date, vigor in 3 of 5 estimates, disease score, 1st and 2nd cuts and total yield in 1965.

8. Lupines. The greatest present hazard to production of blue lupines in the South is winter injury. Winterhardiness of an introduction from Portugal has been incorporated into disease-resistant, soft-seeded forage types. Two lines--64-91 and 64-187--have been increased for more extensive evaluation. A cooperative exchange program is underway in which elite lines from the Tifton, Ga., program are crossed with reduced shattering lines from Australia. Segregating lines are screened for desirable characters at both locations.

Because of the interest in white lupines in Arkansas and adjoining States, hybridization of a winter-hardy, high-alkaloid, hard-seeded strain with non-hardy, soft-seeded, forage types has been initiated in the cooperative program at Tifton, Ga.

Previous studies in the cooperative program at Tifton, Ga., have indicated that blue lupine is 100% self-pollinated. Evidence was obtained that a low rate of cross pollination takes place. In a group of lines with recessive seedling markers, 0.139% of the seedlings were identified as products of cross pollination in the previous generation. The consequence of this finding to the breeding program and to the maintenance of varietal purity by the seed producer is significant.

9. Sericea lespedeza. Four sericea populations were advanced to the stage of testing for forage quality and yield. Sufficient seed was produced of three of the populations for grazing trials at Raleigh, N. C. The best low tannin strains when cut for hay produced 85% as much forage as common types. Continued selection is expected to bring the production of new strains up to levels of the common types. Crosses have been made between high and low tannin lines to determine whether genetic differences in secondary phenolics exist in sericea.

10. Crownvetch. Plants varying in types of growth and maturity, and in forage and seed yields, have been selected from spaced plantings of varieties and strains at several locations. The species can withstand frequent partial defoliation as evidenced by cutting at 2-week intervals.

At Raleigh, N. C., progenies from over 100 crosses of clones greatly different in type showed wide variation, while progenies of crosses between clones of similar but extreme types were uniform and like the parents. This suggests that any desirable type can be fixed with ease through selection. Fine stem, fine leaf types, flowered earlier than large stem, large leaf types.

B. Diseases

1. Starch deficient in red clover crown pith susceptible to internal breakdown. At University Park in Pennsylvania, starch was deficient or absent in deteriorated and adjacent tissues of crown pith exhibiting internal breakdown (IB). Topically applied phenolic substances caused some discoloration of crown tissue but susceptibility to discoloration was not associated with susceptibility to IB. Clover and other plant debris, added to the soil, did not influence prevalence of IB. IB did not differ for early, intermediate, or late-flowering English red clovers and was not affected by photoperiodic treatments.
2. Insect control improves persistence and decreases virus diseases of red clover. Greater forage yields and better plant stands in the second-harvest year of red clover at University Park, Pa., were attributed to insecticide applications. Two percent of plants under cages were infected with virus; 30% of noncaged plants exhibited virus symptoms.
3. Susceptibility of lupines and other legumes to nematodes. In co-operative studies with an ARS nematologist at Tifton, Ga., blue, yellow, and white lupines were evaluated for reaction to Meloidogyne arenaria, M. hapla, M. javanica, M. incognita var. incognita, and var. acrita. M. arenaria was the most damaging species on blue and white lupines, but yellow lupine was moderately resistant. The other nematode species caused moderate galling on blue and white lupines and light to moderate galling on yellow. Reaction of seedling plants of other legumes also was studied. Velvet beans were resistant to four nematode species. Varieties of Glycine javanica were resistant to all species except M. arenaria. Desmodium uncinatum was resistant to M. incognita and to M. incognita var. acrita but susceptible to M. arenaria and M. javanica. Desmodium intortum and D. tortuosum were resistant to all four species.
4. Root and crown disease of crownvetch at Tifton, Ga. On a sandy soil, crownvetch proved to be susceptible to Rhizoctonia solani and Fusarium sp. in May, and Sclerotium bataticola and R. solani in mid-summer. This

suggests that crownvetch is not well adapted in this region.

5. Diseases of summer annual legumes at Tifton, Ga. Spring planted Lotononis bainesii was severely damaged by Rhizoctonia solani. Anthracnose (Colletotrichum dematium f. truncata) on Aeschynomene americana was sufficiently destructive to warrant dropping this entry from evaluation at Tifton.

6. Seed-borne cucumber mosaic virus survives prolonged storage. Blue lupine seed harvested from cucumber mosaic virus (CMV) infected plants at Tifton, Ga., during the spring of 1962 continued to show high incidence of seed-borne CMV in 1966. This demonstrates that CMV cannot be eliminated from lupine seed by prolonged storage.

7. Taxonomy of a birdsfoot trefoil root rot pathogen. Because of priority, the generic name Leptodiscus cannot be used. The fungal species name was therefore changed to Mycoleptodiscus. Another species, isolated from roots of birdsfoot trefoil, M. sphaericus, was described. The fungus has been found in New York, Maryland, Virginia, Illinois, and Missouri. The fungus is apparently saprophytic as well as parasitic.

8. Cucumber mosaic virus (CMV) in crownvetch. At Beltsville, Md., an isolate of cucumber mosaic virus (CMV) was identified in a clone of crownvetch, the first record of a virus naturally occurring in the species. The virus antigen reacted positively with antisera specific for: 1) CMV-Y, Beltsville, Md., 2) an unknown bean virus from Prosser, Wash., 3) peanut stunt virus from North Carolina, 4) tomato aspermy virus from England, 5) a chrysanthemum virus from Holland, and 6) a chrysanthemum virus from the U. S. The crownvetch virus isolate not only relates these isolates to one another and to CMV, but shows properties as a "universal" CMV antigen.

C. Quality and Variety Evaluation

1. Clovers. A naturalized ecotype of subterranean clover was increased in Mississippi and distributed for interstate evaluation; the species seems capable of reseeding under heavy grazing. Frontier crimson clover produced more fall and winter forage than any other winter annual legume evaluated in Mississippi. Arrow leaf clovers appear especially sensitive to spring defoliation as related to reseeding potential. Two Wisconsin red clover synthetics, resistant to powdery mildew and northern anthracnose, were superior to Lakeland for first harvest year yields. Zigzag clovers in Colorado, ranging from pasture to hay types, exhibited good rhizomatous growth under early and late cutting management; flowering in the spring was markedly influenced by date of last harvest the previous year. Evergreen, Denta, and Goldtop sweetclovers were superior yielding varieties in Nebraska for the past 4 years.

2. Promising new legumes. Over 800 species of native and introduced legumes were evaluated in a PL-480 project in Brazil. Stylosanthes gracilis TRI 1022 was outstanding and is being increased for release to other experiment stations. Two native Centrosema pubescens selections are being more extensively studied.

3. Desmodium sp. At Tifton, Ga., the perennial Desmodium uncinatum appeared to be adapted to the region. D. uncinatum with Coastal bermuda-grass fertilized at 0, 50, 100, and 200 lbs. of nitrogen and cut at 3- and 6-week intervals was more productive than Coastal alone. Harvests every 6 weeks were more productive than more frequently cut plots. Two hundred pounds of N reduced stand of the legume. Legume stands were greater under the 3-week cutting system. All five accessions of D. uncinatum survived the winter in space plants, whereas all 6 accessions of D. intortum, winterkilled.

D. Physiology and Biochemistry

1. Excised ovules cultured on artificial media complete interspecific hybridization. Interspecific hybridizations among white clover and two closely related species were successfully made in South Carolina via culture on artificial media of fertilized, excised ovules.

2. Flowering requirements determined for new species of clover. In South Carolina, profuse flowering of Trifolium occidentale was obtained only by cool temperature and short photoperiod in the seedling stage, followed by warm temperature and long-day treatments.

3. Growth of red clover pollen tubes through excised pistils. Red clover pollen tubes grew through less than 1% of intact pistils in incompatible selfings. At Lexington, Ky., greatest pollen tube growth in excised pistils submerged in nutrient media was obtained in media containing 0.050 g Tween 20, 0.050 g boric acid, and 83 g raffinose per liter, at a temperature of 15°C.

4. Self-seed set on excised flower stems of red clover. A technique for producing self-seed in normally self-incompatible red clover was developed at Lexington, Ky. Stems, excised in the bud stage, were placed in jars with 2 1/2% sucrose, boric acid, and Tween 20 at 50 ppm each, at 35°C until florets opened. Florets were then self-pollinated and cultures subsequently held at 20°C for 24 hours, and at 30°C for 2 weeks. Ninety percent of plants of Kenland red clover produced 10% self-seed set with this technique.

5. Persistence in red clover not associated with chemical composition. In Kentucky studies, red clovers varying in persistence did not differ in leaf analyses for each of 16 mineral constituents, nor for total sugars, reducing sugars, or sucrose.

6. Nature of resistance to sweetclover weevil. In contract research with University of Nebraska, a bioassay was developed for selecting sweetclover constituents which stimulate or deter feeding by the sweetclover weevil; one stimulant and two deterrents were detected.

7. Free amino acids in Lathyrus sp. Amino acids in various tissues of 16 species of Lathyrus were determined through a PL-480 project in Poland. The non-protein amino acid, homoserine, was widely distributed within the genus. High levels were found in actively growing tissues, in flowers, young pericarps, and in young seed, but not in mature seed. This suggests that homoserine is the chief form in which nitrogen is transported to developing seeds and is an important metabolite in protein synthesis. The toxic amino acids responsible for "Lathyrism" in grazing animals were found in seed of many of the species. Two perennial species, L. sylvestris and L. latifolius, have been grown to a limited extent in the United States. The leaves, stems, flowers, and seeds of both species contain one or more of the toxic amino acids and hence are of little value as forage plants.

8. Alkaloids of Lupinus sp. The metabolism of alkaloids in the three Lupinus species, L. albus, L. angustifolius, and L. luteus, has been studied in a PL-480 project at the University of Warsaw in Poland. The greatest accumulation of alkaloids in bitter as well as forage types occurs during a relatively short period after the beginning of pod formation on the main stem. After this period the total alkaloid content does not change significantly. Studies of the amino acids, lysine and arginine, proposed by others as alkaloid precursors, were not substantiated. It appears questionable that either of these two basic amino acids are at all involved in alkaloid biosynthesis. The causes of the differences found between forage and high alkaloid types require further investigation.

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FORAGE GRASS AND TURF BREEDING AND GENETICS, DISEASES, QUALITY
AND VARIETY EVALUATION, AND PHYSIOLOGY AND BIOCHEMISTRY

Crops Research Division, ARS

Problem. The active research program includes less than 1/3 of the 90 introduced and native grasses of importance to United States Agriculture. Seedlings of current grass varieties often fail to become established because of insufficient seedling vigor, seedling and mature plant drought tolerance, ineffective water utilization and lack of disease resistance. Plant diseases which reduce yield and quality of forage and seed contribute to loss of stand of established grasses grown for either forage or turf use. Improving forage quality by enhancing constituents influencing digestibility and intake is one area in need of intensive research. Preliminary research has shown that such improvements can be made in bermudagrass. The criteria for more drought tolerant range grasses with improved water use efficiency are not clearly defined and more research is needed before advances through breeding can be expected. Additional basic research in physiology, genetics and cytology with both cool-season and warm-season grasses are needed before substantial nutritional and yield improvements can be attained in forage and range grasses. Problems remain unsolved in regard to management and maintenance of turfgrass for private and public use. The public invests 4 billion dollars annually in establishing and maintaining turf. A broadly based research program is needed to solve current as well as future problems related to different requirements of use, climate, and soil in the diverse turfgrass regions of the United States.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agronomists, geneticists, and plant pathologists engaged in both basic and applied research. Forage grass and turf research is underway at Tucson, Ariz.; Tifton, Ga.; Lexington, Ky.; Beltsville, Md.; State College and Stoneville, Miss.; Lincoln, Nebr.; Mandan, N. Dak.; Woodward, Okla.; University Park, Pa.; College Station, Tex.; Logan, Utah; and Madison, Wis. All work is conducted in cooperation with the respective State Agricultural Experiment Station.

The third year of a 4-year contract with the University of Kentucky on relationship of plant pathogens to toxicity and forage quality in tall fescue was completed.

Five PL 480 projects are active in India; namely, Cataloguing and classifying genetic stocks of Pennisetum spp.; The establishment of linkage groups in Pennisetum typhoides; Pollen storage and serological classification; Genetic evaluation of grain and fodder quality in millet, and cytogenetics of grass species in the tribe Andropogoneae. A PL 480 project in Rio Grande do Sul, Brazil, involving ecological and cytological

studies and genetic improvement of forage grasses and legumes is being terminated.

The Federal scientific effort devoted to research in this area totals 15.4 scientist man-years. Of this number 11.8 are devoted to breeding and genetics, 0.7 to diseases, 1.0 to quality and variety evaluation, and 1.9 to physiology and biochemistry. The Extramural Program is approximately 0.5 scientist man-years in diseases.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 128.0 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Studies suggest all crested wheatgrass is a single breeding population. Cytological and breeding studies at Logan, Utah, suggest that Agropyron desertorum and other crested wheatgrasses should be designated as subspecies and varieties of A. cristatum and that they can be considered a single breeding population regardless of ploidy level. For instance, chromosome pairing in the triploid A. desertorum ($2n=21$) was similar to that in autotriploid A. desertorum. Genomes were homologous except for a small inversion and cryptic structural differences. Pairing in the A. cristatum X A. desertorum triploids indicated that the A. cristatum and A. desertorum genomes differed by several structural chromosome rearrangements including interchanges and inversions. Although A. desertorum is an apparent autotetraploid, its origin directly from the only known form of diploid A. cristatum appears doubtful. A. cristatum and A. desertorum contain the same basic genome and do not appear to be distinctly different species in spite of morphological and ploidy differences.

2. Cytology of Hodo sorghum x johnsongrass hybrids suggest close relationship between the parent species. At State College, Miss., meiosis of the sorghum variety Hodo was slightly more irregular than that reported for other varieties of sorghum because of a higher frequency of chromosome quadrivalents. Meiosis of the fertile interspecific hybrid between Hodo and johnsongrass ($2n=40$) deviated only slightly from meiosis of johnsongrass. Studies of chromosomes during meiosis of the interspecific hybrid support the hypothesis that johnsongrass is an autopolyploid derived from sorghum. Breeding lines have been developed from these hybrids with improved seed set, forage yield, resistance to lodging and high carbohydrate content. Five lines are undergoing further testing for forage yield and quality.

3. Breeding methodology for evaluation of pearl millet introductions.

A breeding procedure was developed at Tifton, Ga., which will increase combining ability of pearl millet introductions. First the introductions are crossed to three superior inbred lines of pearl millet. This is followed by a 3-year inbreeding program. The inbreds were evaluated as male parents following crossing onto cytoplasmic male-sterile 18 and cytoplasmic male-sterile 23. The results indicated that introductions gave greater single-cross yields when they had been crossed previously to the inbreds as compared to males developed directly from these introductions. The study also showed that the cytoplasmic male-sterile Tift 23A was a better female line than Tift 18A for making single-crosses with most pearl millet introductions. The best introductions sometimes gave males which yielded nearly 50% more than males developed from the poorest introduction in a particular test.

4. Breeding methodology for specific combining ability in crested wheatgrass.

Two test crosses were compared with open pollination in evaluating crested wheatgrass genotypes for seed yield and seed size at Mandan, N. D. The three tests were similar in delineating the genotype which most effectively transmitted both traits to its progeny. The test-cross performance of this genotype illustrates the importance of specific combining ability in clonal evaluation. One of its two test crosses was significantly higher than the tester cross in both seed yield and seed size, while its other test cross was higher in seed size only. For each of the two characters, the 10 highest ranking clones as judged by the open pollination test included 2 or more of the 4 highest performers in each test-cross series. The study, which demonstrates the value of open pollination progeny testing for initial clonal evaluation, indicates the need for detailed information on genotypes prior to formulation of synthetics.

5. Blaze little bluestem released.

Blaze little bluestem, developed at Lincoln, Nebr., was released in cooperation with the Nebraska Agricultural Experiment Station. Blaze is a winter-hardy, late-maturing variety recommended for use in pasture mixtures or warm-season grasses and in conservation plantings in central and eastern Nebraska and adjacent areas in bordering states where little bluestem is grown. The foliage is bright to dull green, turning to a deep anthocyanin red at maturity in the fall. In tests in Nebraska, Blaze has proved superior in seedling establishment and forage yield as compared with other strains.

6. Pathfinder switchgrass released.

Pathfinder switchgrass was released in cooperation with the Nebraska Agricultural Experiment Station. Pathfinder switchgrass was developed by hybridization and selection from the Nebraska 1953 domestic collections and exchanges of switchgrass. The new variety is winter-hardy, vigorous, leafy, late-maturing, and rust-resistant. It is recommended for forage use and conservation plantings throughout Nebraska and adjacent areas in bordering states where switchgrass is adapted.

7. Higgins buffelgrass released. Higgins buffelgrass was released in cooperation with the Texas Agricultural Experiment Station. Higgins is the first artificially produced apomictic crop variety which has resulted from the use of a new plant breeding concept developed at College Station. The new method involves control and manipulation of apomixis, a form of reproduction in which seeds are produced without fertilization. Higgins is a single plant selection among the first generation selfed progeny of a heterozygous sexual plant. This apomictic variety is superior in overall performance to present buffelgrass varieties. Higgins is a good seed producer. It has a strong rhizomatous root system with an excellent rate of spread and persistence. Higgins, which is recommended as replacement for present buffelgrass varieties, should be planted in areas where these varieties are not subject to winterkilling.

8. Dwarf cytoplasmic male-sterile pearl millet released to plant breeders. Tift 23DA and its maintainer Tift 23DB, developed at Tifton, Ga., was released in cooperation with the Georgia Agricultural Experiment Station. Tift 23D pearl millet is a highly disease-resistant, many cloned, medium to fine stemmed dwarf inbred. Tift 23DB was developed by transferring a dwarf gene, d_2 , from Tifton inbred 239 through a backcrossing program. Dwarf Tift 23DB was then used to dwarf the cytoplasmic male-sterile Tift 23A by a series of backcrosses of the hybrid to Tift 23DB. Because the dwarf Tift 23D has less stem but the same leaf number as Tift 23, the dwarf lines have a higher leaf percentage and are more lodge-resistant. Dwarf Tift 23DA could give short, very leafy hybrids that would be superior to the tall types in forage quality.

9. Coastcross 1 bermudagrass, a newly released variety with high forage quality. Coastcross 1 bermudagrass was released in cooperation with the Georgia Agricultural Experiment Station. Coastcross 1 is a forage bermudagrass hybrid resulting from a cross between an introduction from Kenya and Coastal bermudagrass. The variety yields about equal to Coastal but is 11-12% more digestible. In preliminary feeding trials steers gain up to 30% more on Coastcross 1 than on Coastal. Coastcross 1, which is completely sterile, is resistant to foliar diseases and to the sting nematode.

10. Spittlebug injury on bermudagrass. The two-lined spittlebug, *Prosapia bicincta*, when feeding on Coastal bermudagrass causes sustained damage to the above-ground growth and significantly reduces root production. The toxin which the insect injects into plant stems does not appear to have a direct toxic effect on underground plant parts. The reduction in root development and sod reserves appears to involve cessation of photosynthesis. Age of adult insect does not appear to be a factor in causing phytotoxemia of Coastal bermudagrass. There was no significant difference in the amount of damage caused by males and females. Among 400 bermudagrass accessions screened for resistance at Tifton, Ga., 5 showed lower damage ratings in the field and in one greenhouse test. None of the 5 is immune to spittlebug injury but the injury appeared less severe.

11. Promising sexual dallisgrass identified. Obligate apomixis is the usual method of reproduction in dallisgrass. In the past only one sexual ecotype has been identified. This remarkably uniform ecotype has extremely poor forage characteristics. The sexual ecotype does not hybridize readily with apomictic types, and lack of variability has prevented improvement through selection. A PL 480 project in Rio Grande do Sul, Brazil, has resulted in a collection of numerous Paspalum species which are being evaluated at College Station, Tex., and State College, Miss. Five distinct sexual ecotypes of dallisgrass have been identified. All are highly variable and some contain vigorous, decumbent plants. Efforts are now underway to cross these selections with the apomictic, common and prostrate types. Selections have also been made within the sexual lines. In this material plants have been found with outstanding forage and seed characteristics. At State College, Miss., the yellow-anthered sexual dallisgrass and common, apomictic dallisgrass have been hybridized. When the sexual parent is used as the female, the F_1 hybrid is sexual. Three hybrids had, respectively, 55%, 64.5%, and 77.7% seed-set as determined by germination tests. Selections have been made in the F_2 population from each of these three hybrids for the semi-decumbent, common dallisgrass type. Semi-decumbent plants with better than 70% seed-set have been isolated.

12. Corn pollen remains viable following 8 days of storage. A PL 480 project in India involves the study of factors which may extend pollen viability in storage. Corn pollen, which showed 4% germination in vitro after 8 days of storage at 8°C and 72 to 92% RH, gave good seed-set upon pollination with an inbred line. Pollen of wheat and sorghum, on the other hand, lost all viability after 24 hrs. of storage.

13. Genetics of several qualitative characters established in pearl millet. The inheritance of 14 qualitative characters in pearl millet was determined in a PL 480 project in India. The character floret-bearing bristles was shown to be controlled by two dominant genes; one being responsible for bristle and the other causing florets on the bristles. In absence of the gene controlling bristles, the floret bearing gene was ineffective. Some characters were controlled by two dominant or recessive complementary genes, one by three dominant complementary genes. Several single recessive genes were found to control expression of various characters.

B. Diseases

1. Spring dead spot disease on bermudagrass remains an unsolved puzzle. The following pathogens have been isolated from diseased bermudagrass crowns and rhizomes growing in areas with a known history of "Spring dead spot": Helminthosporium stenospilum, H. rostratum, H. spiceferum, Rhizoctonia solani, and Curvularia spp. At Tifton, Ga., the spring dead spot disease was found to be unrelated to levels of potassium in the soil or in bermudagrass sprigs. Two fungicides, nabam and a coordination

product of zinc ion and [ethylenebis (dithiocarbamate)] manganese, gave effective control of the spring dead spot disease when applied at three monthly intervals in the fall at 8 oz. per 1,000 sq. ft. and watered into the turf with 1/2 inch of water. Less frequent applications were not successful. Various cultural practices including fertilizer studies and sod detaching have been initiated in attempts to find a practical solution to the spring dead spot problem.

2. Kernel smut of pearl millet controlled by systemic fungicides.

Research at Tifton, Ga., has shown that Tolyposporium kernel smut of pearl millet is not readily controlled by seed treatments in areas where the smut has become established. Because the major source of primary inoculum overwinters in the soil, infection results from aerial movement of spores or sporidia to the florets. Two systemic fungicides, 2,3-Dihydro-5-carboxanilido-6-methyl-1,4-oxathiin-4,4-dioxide (DCMOD) and 2,3-Dihydro-5-carboxanilido-6-methyl-1,4-oxathiin (DCMO), were found to be highly effective in reducing incidence of smut on pearl millet. The chemicals were applied when a majority of the heads had just emerged from the boot and before stigmas were showing. The heads and the top 2 feet of the foliage were sprayed until completely wet. These fungicides show promise in controlling kernel smut in seed production fields of pearl millet where smut might be a problem.

C. Physiology and Biochemistry

1. Nutritional requirements of Poa annua L. Information on the nutritional requirement of annual bluegrass (Poa annua L.), generally considered a weed in turf, was obtained at Beltsville, Md., in order to provide better control. The total yield of tops and roots was greater when annual bluegrass was grown in silt loam as compared to loamy sand regardless of two pH levels, pH 4.5 and 6.5. The root yields, however, from plants grown in loamy sand were almost three times greater at pH 6.5 than 4.5. High pH gave a significant increase in top yield on loamy sand. Individual comparisons for treatment effect show that N, P, and K contribute most for both top growth and root yields in the order mentioned. Plants grown in silt loam at pH 6.5 produced significantly more seedheads than at pH 4.5.

2. Chemical composition as indicator of nutritional value of tall fescue pastures. Tall fescue varieties and ryegrass x tall fescue hybrids were sampled during the growing season at Lexington, Ky., for crude protein, crude fiber, total sugars, silica content, and moisture. These chemical constituents were related to palatability and in vitro digestibility. Seasons had greater influence on sugar content of the forage as compared to other constituents studied. The mean sugar content for all grasses range from 8.4% in summer to 19.1% in the fall. Fluctuation in percent digestibility followed a similar pattern throughout the year. Total sugar was very closely correlated with digestibility. The close association of sugar and digestibility suggested that sugar content may be a

good indicator for determining nutritional value of grasses. The technique will enable plant breeders to screen large populations of plants when selecting for improved nutritional value. The annual ryegrass-tall fescue hybrids have consistently higher sugar content and are more digestible compared to Kenwell and Kentucky 31 tall fescue.

3. Seed dormancy broken in Lehmann lovegrass. Seed of Lehmann lovegrass which is completely dormant following harvest reaches a non-dormant condition following 150 weeks storage at room temperature and low humidity. At Tucson, Ariz., 8 seconds of cylinder scarification was most effective in breaking dormancy. Seed treatments with gibberellic acid, thiourea, kinetin, indoleacetic acid, potassium nitrate, extended prechill, gamma radiation, and radio frequency electrical fields were ineffective in breaking dormancy. Dormancy was not correlated with the presence or absence of any identifiable phenolic compounds. Several seed sources were compared for seed dormancy and seedling drought tolerance. Sources with no seed dormancy were the lowest in seedling drought tolerance. Bunch type experimental entries of Lehmann lovegrass were identified with high seedling drought tolerance.

4. Pearl millet seed dormancy is affected by many factors. At Tifton, Ga., stepwise regression analyses of the effect of four characters indicated that ripening period was the single most important cause of reduced seed germination in four inbreds of pearl millet. In inbred 23, however, date of anthesis was more important. In this case, seeds from heads bagged early in the season germinated less than seed from heads bagged later. Seed storage period and method of seed drying also affected the germination of the inbreds. The inbreds were differentially affected by most treatments. No single factor was responsible for failure of a seed to germinate.

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PASTURE AND RANGE QUALITY, PHYSIOLOGY AND BIOCHEMISTRY,
SEEDING AND ESTABLISHMENT, PROCESSING AND MANAGEMENT

Crops Research Division, ARS

Problem. In the United States grazing lands occupy almost three times as many acres as all harvested crops. With increased demand for livestock products, pasture and rangelands must be more productive to offset competitive demand for grains by people. As greater pressure for livestock feed is placed on pasture and rangelands, research must supply improved varieties, better pasture and rangeland management practices and more efficient utilization of forage. Greater research emphasis must be placed on improving quality of forage and efficiency of production. This involves determining biochemical constituents in plants that are basic to improved animal nutrition. Pasture and rangeland research needs to be intensified to determine the most effective management systems for providing feed throughout the grazing season. Preliminary research suggests that the grazing season can be significantly extended by alternating use of native and introduced grasses. This promising area of research needs to be expanded to include other species and management systems under different environmental conditions. Above all, research is needed on forage species and management systems so that in spite of hazards such as drought, winter injury, and severe grazing pressure, production and persistence can be optimized.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agronomists, plant physiologists, range scientists, and chemists engaged in basic and applied research on the management and improvement of grazing lands, native meadows, and improved pastures. All work is cooperative with the respective States, with the U. S. Forest Service, and Bureau of Land Management, in areas where grazing is integrated with lands under their control. Research is in progress at Flagstaff, Ariz.; Berkeley, Calif.; Ft. Collins, Colo.; Gainesville, Fla.; Tifton, Ga.; Lafayette, Ind.; Beltsville, Md.; St. Paul, Minn.; Columbia, Mo.; Bozeman, Mont.; Miles City, Mont.; Reno, Nev.; Las Cruces, N. Mex.; Raleigh, N. C.; Mandan, N. Dak.; Woodward, Okla.; Burns, Oreg.; University Park, Pa.; Logan, Utah; and Pullman, Wash. Research at Bozeman, Mont., and Mandan, N. Dak., is conducted cooperatively with Soil and Water Conservation Research Division and at Miles City, Mont., with Animal Husbandry Research Division.

Of four PL 480 projects, two are in Israel. One concerns developmental physiology of perennial pasture grasses. The other investigates establishment and maintenance of seeded dryland range under semiarid conditions. Two projects in Poland concern evaluation of the ornithine cycle in higher plants and inheritance of amino acid contents in leguminous forage plants.

The Federal scientific effort devoted to research in this area totals 32.2 scientist man-years. Of this number 5.8 is devoted to quality; 10.3 to

physiology and biochemistry; 6.1 to seeding and establishment; 0.3 to processing; and 9.7 to management.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 68.6 scientist man years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Quality

1. In vivo digestibility and intake variability defined. Cooperative results from 6 experiment stations in the Midwest could be compared if standardized procedures were followed. The greatest source of variability was associated with animals and not the individual stations. Precision of forage quality evaluation can be improved by using more animals per trial. Accurate estimates would then be assured from results of three participating stations.

2. Basic studies on chemical composition and forage quality. At University Park, Pa., samples of several grasses had an average hemicellulose content of 22%, whereas that for alfalfa was 13%. The hemicellulose: cellulose ratio for grasses and legumes were 0.7 and 0.4, respectively. Digestibility of hemicellulose was similar for the grasses and alfalfa. Results to date show that there are no constituents so far studied that are correlated directly with voluntary intake except those which are also correlated with digestibility. Samples with a greater proportion of cellulose to hemicellulose also had a larger although not consistently greater negative correlation with voluntary intake.

3. Quality of alfalfa-brome haylage compared in concrete-stave and air-tight silos. A 2-year feeding trial with beef cattle at St. Paul, Minn., indicated little difference in quality of alfalfa-brome haylage due to type of storage structure. Forage in air-tight silos lost up to 3% dry matter while those in concrete-stave silos lost as much as 9% dry matter.

4. Russian wildrye retains relatively high digestibility. Russian wildrye has high digestibility early in the growing season and digestibility remains relatively high considering the universal decline in herbage digestibility as it matures. Studies at Mandan, N. D., revealed a digestibility of 71.78% on June 15, 61.52% on June 24, 53.01% on August 2, and 45.91% by October 5 from samples collected in a pasture being grazed yearlong. The feed-feces technique of Van Soest was used. Crested wheatgrass began with comparable values, but declined faster as the season advanced.

B. Physiology and Biochemistry

1. Photosynthetic efficiency of Coastal bermudagrass leaves. Under field conditions at Beltsville, Md., photosynthetic efficiency of Coastal

bermudagrass leaves declined rapidly 2 weeks after emergence. Sun-grown leaves were dead 4 weeks after emergence while shade-grown leaves lived for slightly more than 6 weeks. These results may explain the observation that forage yields of Coastal are as high when it is cut back frequently to 3/4 inch as when it is cut back less frequently to 3 inches. Under the close cutting leaves are always young and efficient.

2. Adaptation of photosynthesis. At Beltsville, Md., studies show that orchardgrass plants have the capacity to adapt to the temperature at which they are grown. However, the maximum photosynthetic rate for plots grown at 10 C is less than one-half that of those grown at 20 or 30 C. Pangolagrass, on the other hand, did not show the same temperature adaptation. Photosynthetic rates were maximum at 30 C for plants grown at 20 to 30 C. Photosynthesis of plants grown at 10 C was nearly completely inhibited and did not respond to increasing temperatures.

3. Net assimilation rate related to specific leaf weight in alfalfa. At Beltsville, Md., specific leaf weight (SLW), the ratio of leaf area and leaf weight, appears to be genetically controlled and is directly associated with net assimilation rate (NAR) in alfalfa. As SLW increased, so did NAR. This suggests that photosynthetic efficiencies may be increased by selecting for SLW.

4. Characterization of germination inhibitor in alfalfa. A water extract from dark-colored alfalfa seed inhibits germination and inhibits subsequent root growth. Extracts from yellow or light colored seeds did not inhibit germination. The inhibitor has been isolated by paper chromatography at Gainesville, Fla. Fluorescence in ultraviolet light and isolation in ethyl ether suggests that a portion of the inhibitor is a furocoumarin. Some of the inhibitor is found in the seed coat but the bulk of it is found in the seed.

5. RNA metabolism and protein synthesis affected by phosfon-S. Phosfon-S is a substance which inhibits stem elongation in garden peas. It decreased soluble RNA and increased ribosomal RNA. Thus, nucleic acid of treated plants is characteristic of young plant tissues. Phosfon-S also slowed protein synthesis. Other research at Gainesville, Fla., suggests that phosfon-S may preferentially complex with DNA and as such would be localized in the nucleus.

6. Cheatgrass, a heavy seed producer, seldom germinates completely first year. The popular idea that in a favorable year essentially all cheatgrass seed germinates is false according to work conducted at Logan, Utah. The fall of 1965 was warm with abundant moisture. By late fall about 475 seedlings had emerged per sq. ft. of cheatgrass sod, but an additional 400 to 700 seedlings emerged when the sod was removed to a greenhouse and watered. Sods checked in the late spring of 1966 contained from 600 to 1000 seedlings per sq. ft., but these sods, under favorable greenhouse conditions yielded an additional 150 to 400 seedlings per sq. ft. The data also point out the

numerical advantage and hence the competitive effect cheatgrass has on crested wheatgrass seedlings where 5 lbs/acre represents about 20 seeds/sq. ft.

7. Forage plants respond differentially to temperature and moisture.

Germination and seedling survival under high and low soil temperature and 5 moisture regimes sharply differentiated important arid southwestern forage species in laboratory studies conducted at Las Cruces, N. M. Of 14 species tested with ample moisture only black grama, Rhodesgrass and Vaughn sideoats grama gave both good germination and good seedling survival under the high temperature regime. Sacaton, vine mesquite, bush muhly and fourwing saltbush gave better germination and better seedling survival at the low temperature regime. In the low regime the daily soil temperature cycle ranged from 70F. to 105F. while in the high from 70F. to 135F. Black grama and Boer lovegrass gave excellent emergence under the low temperature regime when soil moisture was adequate for 3 days. Under the high temperature regime black grama was superior.

8. Blue grama and western wheatgrass differ in soil moisture extraction.

Soil moisture determinations at one-foot intervals to 4 ft. depth at Mandan, N. D., revealed much more complete moisture extraction under western wheatgrass than under blue grama. In the average rainfall year of 1966, soil under blue grama sod contained 3.05, 3.02, 2.81, and 2.91 inches/foot while western wheatgrass values were 1.84, 1.15, 1.14, and 1.37, respectively, for 1st to 4th foot. The values represent averages of 8 determinations extending from October 1965 to October 1966. A mixture of western wheatgrass and blue grama closely resembled western wheatgrass in moisture extraction. The study was conducted on excellent grass stands sown in June 1963.

9. Leaf analysis a guide to fertilizer needs of forage plants. Nitrate nitrogen concentrations in selected leaf tissue of tall and intermediate wheatgrass and Idaho fescue revealed the critical level to be approximately 500 ppm in studies at Berkeley, Calif. When tissue contains more than 500 ppm the nitrate needs of these species are adequately met, while below 500 ppm the plants will respond to applications of N. The nitrate, phosphate, and sulfate critical concentrations in young leaf tissue of Italian ryegrass were found to be 1000, 750, and 100 ppm, respectively.

10. Phosphorylation occurs in seeds at low water potential. At Pullman, Wash., seeds of crested wheatgrass were able to synthesize unidentified phosphate esters when their water potentials were reduced to -880 atmospheres during a 5-day period of absorption under controlled relative humidity. When the water potential was reduced to -130 atmospheres the seeds synthesized adenosine triphosphate, uridine diphosphate hexose, nicotinamide adenine dinucleotide, and some other unidentified phosphate esters. As the water potential was further lowered additional activities and greater concentrations of phosphorylation products occurred. The water potentials studies ranged from -2600 to -40 atmospheres, representing seed moisture contents of 6 to 30%, respectively.

11. The ornithine cycle in higher plants. Work on this PL 480 project in Poland has shown that natural inhibitors in higher plants may regulate the operation of the ornithine cycle. Investigations have established the presence of all enzymes of the ornithine cycle in various higher plants.

12. Inheritance of amino acid content in forage plants. Research on a PL 480 project in Poland shows that nitrogen, phosphorous, and potassium treatment had little effect on protein content or percentage of lysine, histidine, or arginine in alfalfa. Work is under way to identify several nonprotein amino acids in forage legumes.

C. Seeding and Establishment

1. Species survive in arid Panoche Hills. A few species represented by annual legumes, a perennial grass, and shrubs may be suitable for seeding in the dry Panoche Hills area along the inner coastal range in central California. Kondinin rose clover, California bur clover, Harbinger medic and Medicago littoralis, and the Yamina variety of cup clover were successful annual legumes. Pubescent wheatgrass A-1488, Atriplex polycarpa and Isomeris arborea were successful perennials. The perennials survived a 10-month period receiving only 1/2 inch of rain in 1966. The annuals reproduced themselves to bridge the dry period. All species were seeded in 1965.

2. Moistening seed treatment hastens seedling emergence. Wetting (but not submerging) seeds of crested wheatgrass with tap water for about 60 hours at 63 F. and then drying them enabled these seeds to germinate and emerge from 1/2 inch planting depth in about 40 hours less time than untreated seeds. The advantage persisted when treated seeds were planted as much as 6 months after the treatment in greenhouse studies conducted at Logan, Utah. During the first 3 days after emergence began, roots from treated seeds were 20 mm longer than those from untreated controls.

3. Fungicides control Podosporiella without lowering seed germination. At Logan, Utah, captan at 8 oz/100 lbs. seed and thiram or Semesan at 6 oz/100 lbs. seed gave excellent control of Podosporiella verticillata if germination and seedling emergence occur soon after planting in either greenhouse or field tests. When germination is delayed several weeks or months, fungus control is fair to good. Captan and thiram can be applied at rates of 12 and 8 oz/100 lbs. seed, respectively, without lowering seed germination. Semesan was not tested at rates above 6 oz/100 lbs.

4. Summer seeding on plowed land best for 4-wing saltbush. At Flagstaff, Ariz., good stands of 4-wing saltbush have been consistently obtained only from summer seeding on plowed land, with seeds planted in shallow furrows. If seeding is done in conjunction with undercutting, the undercutting must be thorough. Dalapon spray was too slow for seedbed preparation involving destruction of blue grama sod.

5. Atrazine fallow increases soil nitrogen: delays seeding. Chemical fallow

using atrazine at 1 lb/acre to aid establishment of perennial grasses was effective in cheatgrass control and also permitted a 4 to 9 fold increase in nitrate-N, in studies conducted at Reno, Nev. Where control plots contained 6 lbs N/acre those chemically fallowed 18 months had from 23 to 58 lbs N/acre in the 0-6" depth. With only .03 to .06 ppm atrazine remaining in the soil, mortality of Amur intermediate wheatgrass seedlings was as high as 14% while .15 ppm atrazine permitted no seedlings to survive. In field practice 1 lb/acre atrazine applied in the fall left .31 to .53 ppm in the top inch of soil the following spring.

6. Time-rate of germination key to seeding success. Research in Israel on a PL 480 project has directed attention to both the short duration and rapid deterioration of conditions favorable for germination and seedling establishment in the revegetation of arid rangeland. Successful seeding is more dependent upon rapid germination than on an ultimate high percentage germination. The two are not related.

D. Management

1. Incidence of bloat reduced by feeding paloxalene/molasses to steers grazing alfalfa-bromegrass. At Lafayette, Ind., steers which consumed 0.5 lb of the paloxalene/molasses block showed no bloat. On the other hand, steers not receiving paloxalene blocks were susceptible to bloat. During a 21-day period, of the animals not receiving paloxalene/molasses blocks, one died and eight required medical attention to relieve bloat stress.

2. Grain supplementation increases lamb production and dollar returns. Results of a 3-year study at St. Paul, Minn., showed that lambs fed grain on alfalfa-brome pastures produced significantly more meat per acre and did it more economically. It made little difference to dollar returns whether or not lambs were weaned as long as they were fed grain. If the lambs were not fed grain those which were unweaned gained more rapidly and yielded slightly greater dollar returns per acre.

3. Summer grasses promising in forage livestock system in Missouri. Several warm-season grasses have been evaluated for 2 years under three simulated grazing systems. Caucasion bluestem and Midland bermudagrass have produced the highest yields during July and August under rotational grazing. Both grasses have persisted and spread into adjacent plots. These grasses, in a forage-livestock system with cool-season grasses and summer annuals, will provide nearly yearlong grazing.

4. Dalapon and 2, 4-DB aid establishment of birdsfoot trefoil. When trefoil is seeded alone weeds are often a problem, but they can be controlled by post emergence application of herbicides. Forage yields from herbicide treated plots were 30% greater than from untreated plots. However, when birdsfoot trefoil is seeded with grass, a post-emergence application is of little value unless broadleaf weeds are abundant.

5. Species altered by N on abandoned cropland. October application of 40 lbs N/acre for 3 consecutive years on abandoned cropland at the Central Plains Experimental Range reduced perennial grasses 43% (principally 3-awn reduced 50%, and sand dropseed reduced 8%), a desirable trend, but increased lambsquarter 14-fold, an undesirable trend, while perennial forbs and other annuals were unaltered. Total herbage production was doubled each year. Heavier rates of N only tended to increase lambsquarter and decrease perennial grasses without changing total yield.

6. Weed control and N fertilizer renovate old crested wheatgrass. A 30-year old crested wheatgrass pasture at Mandan, N. D., was restored to high productivity by control of fringed sage with 2, 4-D and applications of 40 lbs N/acre/year. After highest production the first year of grazing the pasture declined from 133 lbs beef/acre to an average of 70 lbs. the last 7 years of the 30-year period. The control of sage and fertilization for 4 years then resulted in a 4-year average productivity of 159 lbs beef/acre. The highest monetary return over the cost of treatment was for spray only, but a combination of spray and N produced 70% more forage.

7. Guide developed for summer stocking of central plains ranges. Leaving approximately 300 lbs ungrazed herbage per acre at the end of the grazing season leads to maximum sustained returns per acre on arid Central Plains range. The research at the Central Plains Experimental Range near Fort Collins, Colo., showed that over a 23-year period the optimum stocking rate for the 6 months grazing season was 15.6 acres per yearling heifer. Returns per acre were lowered substantially more by overstocking than by understocking. The guide is a major contribution to grazing management on arid Central Plains rangeland.

8. Season long grazing on Russian wildrye superior to rotation. Studies at Mandan, N. D., showed over the past five years the superiority of Russian wildrye when compared with native range or a rotation of crested wheatgrass in spring, native in summer and Russian wildrye in fall. Native range required 5.2 acres/head for 140 days. On Russian wildrye 1.6 acres provided grazing for 142 days and 1.9 acres would have been adequate for 172 days. On the rotation 3.5 acres were required for 172 days. Steer-days grazing/acre were 90 for Russian wildrye, 52 for the rotation, and 27 for native range, and TDN/acre 814.440 and 250, respectively. Either Russian wildrye or the rotation are capable of providing full season grazing while native range cannot be used as early in spring or as late in fall as the others.

9. Seeded pastures for spring grazing profitable in Montana. During the past three years at Miles City, Mont., beef cattle flushed during the spring breeding season on seeded grass-alfalfa pastures, produced 57 pounds more calf per cow-year than those maintained only on native range. The gain was a result of larger calves and a 10% greater calf crop. Early spring deferment on seeded pastures was highly beneficial to the native range which then provided more grazing in late spring and early summer.

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SEED CROP CULTURE AND MANAGEMENT, PHYSIOLOGY AND BIOCHEMISTRY,
DISEASES, AND QUALITY AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. Domestic production of many grass and legume seed crops is well below national consumption. Importation of approximately 75 million pounds of forage-crop seed annually is necessary because technology has not been developed to make seed production competitive with other farm enterprises. Research is needed to investigate the factors that limit tiller initiation, fertilization, and seed formation, and to develop cultural and management techniques including disease control practices that will assure efficient seed production. Fundamental physiological investigations on growth responses of grasses and legumes to various environmental, management, and micro-climate factors are needed to establish the specific requirements for reproduction.

Normal vegetable seed supply is adequate, but geographic concentration of the industry is potentially hazardous and problems of hybrid seed production are becoming economically serious to both the seed and vegetable processing industries. Mechanization of the vegetable industry requires increase of speed and uniformity of seedling development, but improvements in processing quality of vegetables often decrease seed quality. There is insufficient basic knowledge of physiology of seed development and germination as these influence the crop-producing potential of seeds and potential industry mechanization.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-time program on grasses and legumes involving agronomists, physiologists, and pathologists engaged in both basic and applied research. Investigations are underway at Shafter, Calif.; Lafayette, Ind.; Stillwater, Okla.; Corvallis, Oreg.; Logan, Utah; and Prosser and Pullman, Wash. All work is conducted in cooperation with the respective State Agricultural Experiment Stations and the Entomology and Agricultural Engineering Research Divisions. Basic research on the physiology and biochemistry of vegetable seed production, seed germination, and seedling vigor is carried out at Fort Collins, Colo., in cooperation with Colorado State University.

Research on forage seeds is being conducted under PL 480 contracts in Finland, Israel, and West Germany and a Memorandum of Understanding between ARS and the Research Council, Japanese Ministry of Agriculture and Forestry. The influence of environment and management practices on population shifts in cross-pollinated forage-crop varieties when seed is produced in areas outside the regions of origin is being studied.

Vegetable seed research is conducted under three PL 480 projects. Two in India emphasize biochemical factors associated with lack of viability in

rice and ascorbic acid treatment of wheat seeds to increase yield, respectively. A project in Israel is studying submicroscopic changes in developing and germinating lima bean seeds. Research on plant and seed multiplication in Vietnam has been initiated through funds provided by AID.

The Federal research in this area totals 14.5 scientist man-years. Of this number, 6.5 are devoted to Culture and Management, 1.0 to Diseases, 1.9 to Quality and Variety Evaluation, and 5.1 to Physiology and Biochemistry.

The Vietnam staff consists of 11.0 scientist man-years, namely, a project leader, 7 scientists, and 4 seed production advisers.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 20.0 scientist man-years.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Culture and Management

1. Apical dominance is present in some red clover genotypes. Removing or covering heads of red clover in the pre-bloom stage stimulated flowering in three out of four clones at Prosser, Washington. The number of mature heads on a poorly flowering clone was increased 36%. Clones that were stimulated to produce more heads possessed pronounced apical dominance. Thus periodic removal of apical inflorescences allowed development of lateral buds and a continuing increase in a number of inflorescences. Other seed yield components and nectar production were not affected appreciably by the treatments.

2. Nectar sugars vary among alfalfa varieties. At Logan, Utah, nectar of DuPuits alfalfa was higher in glucose and lower in sucrose than nectar of Lahontan, Ranger, and Uinta alfalfas. Some volatile constituents were common to nectar of all the varieties, and most were characteristic of the sap. Variations were noted in the chemical constituents of nectar by varieties and by years. Gas-liquid chromatographic analysis has proved useful in analyzing nectar to identify the pollinator attractants in alfalfa flowers. This information will be used in breeding improved varieties.

3. Improved cultural practices increase seed yield of Western wheatgrass. Inadequate seed supplies of many native cool-season grasses limits range improvement. At Lincoln, Nebraska, better yields of high quality seed of Western wheatgrass were obtained when at least 80 pounds of nitrogen per acre was applied in association with irrigation, either in the fall or spring and at heading time.

4. Growth inhibitors reduce orchardgrass seed viability. Seeds of some varieties of orchardgrass are consistently low in viability. This limits seed supplies and prevents the extensive use of improved varieties. Studies

at Pullman, Washington, show that growth inhibitors are present in higher concentration in seed of the dormant Latar variety than in the non-dormant S-143. Approximately 35% of the inhibitor present in the intact seed of both varieties is located in the lemma and palea, with the remaining 65% in the Caryopsis. Leaching and prolonged dry storage did not significantly decrease the level of the inhibitor. However, when Latar seeds were pre-chilled for 7 to 10 days at 5° C, the inhibitor was reduced to a level equal that in the non-dormant S-143 seed. Seed of both varieties then germinated comparably. The inhibitor has not been identified.

5. Bluestem seed yields are influenced by number of crops harvested in a season. Higher seed yields of grass species adapted to the Great Plains are major objectives. Investigations at Stillwater, Oklahoma, have shown that the highest yields of Old World bluestem selections are obtained from seed crops produced in mid-summer and fall. When three or four seed crops were produced and harvested in a season, the total yield of seed was reduced. The seed yield from two harvests approximates 627 pounds per acre of raw seed with a pure seed content of 30%. Most efficient harvest methods included: (1) topping the seed crop with an elevated sickle bar on a self-propelled windrower; (2) collecting the topped seed crop at the rear of the windrower; (3) cure and thresh with a hammer-mill; and (4) scalp and clean to the desired pure-seed level. The seed yields approximated those from hand harvests. They are significantly higher than yields obtained by direct combining or windrowing plus combining.

6. Life history studies of orchardgrass indicate reasons for decline in seed yields. Studies at Corvallis, Oregon, on the life history of orchardgrass indicate that the decline in seed yield with advancing age of stands is caused mainly by disease and insect pests. The root rot, Fusarium culmorum, killed many tillers but was not equally destructive to all genotypes. Oregon Clone B and Pennlate Clone MIV-17 were highly resistant. As the stand of the orchardgrass clones aged, root rot organisms increased and attacked new tillers. Plants were also weakened by root feeding insects. The weakened plants were susceptible to killing by post-harvest burning. The variation in susceptibility to root rot among the Pennlate clones introduces the possibility that genetic shifts may occur in this and other synthetics due to the differential loss of plants as stands age.

7. Viability of red clover seed remains high under low temperature storage. Retention of seed viability for long periods is important. At Prosser, Washington, red clover seed has been stored at -5° C for six years. During this time, the seed lot has been thawed and refrozen over 300 times. The sample still has hard seed and 95% germination compared to 96% initially.

8. Distribution of foundation seed of forage species. In 1966, 95,954 lbs of superior forage crop varieties were distributed by the Foundation Seed Project in 15 States and Canada. Foundation seed totaling 266,287 pounds was produced in Idaho, New York, Oregon, Texas, and Washington. Foundation Potomac orchardgrass seed is in short supply due to spring-frost damage.

Seed production of this variety has been transferred to western Oregon to reduce possibility of frost damage. The foundation seed supply of other varieties is adequate to meet expected demands in 1967 and to provide reasonable carry-over reserves.

B. Physiology and Biochemistry

1. Some red clover ecotypes require low temperature exposure for development of floral stems. Treatment at 2 or 10° C for varying intervals induced Tammisto red clover plants to flower earlier and more abundantly. At Lafayette, Indiana, up to 95% of plants given low temperature treatment for 12 weeks produced floral stems. This contrasted to 42% of plants flowering without low temperature treatments. The low temperature treatment was followed by a 3-week growth period at 25° C and a 20-hour photoperiod.

2. Pathogens not associated with internal breakdown in red clover. Histological studies of internal breakdown (IB) in red clover at Prosser, Washington, have failed to reveal a pathogen during the early stages of degeneration. Thus, at present, IB appears to be a degeneration of the pith cells in the crown of red clover. Tissue affected with IB is characterized by presence of enlarged cells, low starch content, and nuclear anomalies. The latter consist of enlarged or vacuolate nuclei and multinucleate cells in which the nuclei are aggregated. The anomalies occur in various combinations.

5. Ascorbic acid treatment of wheat seeds. Indian workers under a PL 480 contract, have found that a pre-planting treatment of wheat seeds with ascorbic acid improves plant growth and yield of grain.

6. Growth inhibitors in nonviable rice seeds. Under a PL 480 project in India, a growth inhibitor similar to Abscission II or dormin has been found in nonviable seeds, whereas this factor is lacking in viable seeds.

C. Diseases

1. Chemotherapy of diseases in grasses grown for seed. At Corvallis, Oregon, flag smut (Urocystis agropyri) was inhibited and apparently eradicated in plants of Merion Kentucky bluegrass and in all new growth for 15 months by 20 to 40 pounds per acre of a systemic fungicide 2,3-Dihydro-5-carboxanilido-6-methyl-1,4-oxathiin-4,4-dioxide (DCMOD). Leaf tip scorching occurred within one week after soil was treated with DCMOD. The injury gradually disappeared and was confined to distal portions of older leaves. Plant growth was initially retarded but later increased significantly with control of the pathogen. A closely related compound, 2,3-Dihydro-5-carboxanilido-6-methyl-1,4-oxathiin (DCMO), significantly reduced the incidence of flag smut but failed to eradicate the disease at 15 to 40 pounds

per acre. DCMOD suppressed but did not eradicate stripe smut in common orchardgrass, Merion Kentucky bluegrass, and Pennlu creeping bentgrass. It was not effective in controlling loose smut (Ustilago bullata) in mountain brome nor dwarf bunt (Tilletia caries) in Elgin wheat. However, DCMOD provided good control of stripe rust in Kentucky bluegrass until mid-May, but seed yields were less than for the standard nickel-maneb treatment. DCMO was less effective.

D. Quality and Variety Evaluation

1. Population shifts in Dollard red clover when seed is produced at different locations. Seed of cross-pollinated forage varieties bred in the Eastern and Central States is frequently produced in the Western States. Changes in plant populations may occur. Seed of Dollard red clover produced at Prosser, Washington, 46° lat. and 840 ft. el.; Shafter, California, 35° lat. and 350 ft. el.; and Tehachapi, California, 35° lat. and 3,975 ft. el., was evaluated for several physiologic and morphologic characteristics at Lafayette, Indiana. Seed produced at Shafter and Tehachapi had populations consisting of more flowering plants that were less winter hardy than the populations of the original breeder seed. In contrast, seed lots produced at Prosser had plant populations similar to those of the breeder seed. Varietal changes from the Syn 1 to the Syn 2 generation were not as great as the observed changes from the breeder seed to the Syn 1 generation of increase. When the initial vegetative plant growth was removed as hay, only minor changes occurred in plant populations from seed produced at Prosser. At the two California locations, seedling year seed crops produced populations with more flowering types than seed from two- or three-year-old stands. Harvesting a hay crop prior to the seed crop at Shafter and Tehachapi resulted in plant populations comparable to the breeder seed. Rates of seeding had no effect on subsequent seed plant populations from any of the three locations. The percentage of plants with leaf-mark varied from 5 to 28 percent, but this was not related to any seed production location or management treatment. Correlation analyses show that plant type ratings were related to winter survival. No correlations were found between plant type ratings and leaf mark.

2. Forage crop species grown for seed in different environments vary in growth characteristics. Two hundred thirty-one experimental seed lots of 20 foreign and 11 domestic varieties, representing 10 species, were produced at Prosser, Washington; Logan, Utah; Shafter and Tehachapi, California; and College Station, Texas; as part of national and international cooperative research projects to develop information on the factors influencing population shifts in cross pollinated forage species. Data was obtained on floral development and the components of seed yield at each location. Seed of domestic varieties will be evaluated at Purdue University for population shifts due to climate and management practices. Seed of the foreign varieties will be forwarded to the originating country to be studied for genetic shifts. Most of the foreign varieties are included in PL 480 projects with Finland, Germany, and Israel, and the new cooperative research project with Japan.

3. Seed of two new alfalfas produced. The early seed increases of KS-10 alfalfa, an experimental selection made in Kansas, and Dawson, released in cooperation with the Nebraska Agricultural Experiment Station, were made at Prosser, Washington. Seedling year crops were harvested from each variety. This provided seed for early forage performance tests throughout the country of the KS-10 and for a rapid expansion of certified seed fields of Dawson.

4. Cold resistance of alfalfa varieties rated by germination of seed in solution of different osmotic values. In research under a PL 480 project in Israel, the ratio between the time of germination in water and in 6-atm. mannitol solution was found to be closely related to the apparent winter-hardiness of alfalfa varieties. The test provided good separation between 19 and 21 seed lots of Ranger and Vernal alfalfa, respectively. The seed represented different generations of increase and was derived from a wide latitudinal range of seed production areas.

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WEED AND NEMATODE CONTROL
Crops Research Division, ARS

Problem. Weeds cause losses in crops, orchards, grazing lands, forests, water supplies, and irrigation and drainage systems. These losses can be reduced by finding more effective chemical, biological, mechanical and combination methods of weed control.

Plant-parasitic nematodes occur in all soils used for growing of crops and attack all kinds of plants grown for food, forage, fiber, feed or ornamental purposes. Severity of attack by certain fungi is increased if nematodes are present. Nematodes also have been known to be the vectors of several plant viruses. There is need for improvement in methods of controlling nematodes on grain and forage crops.

USDA AND COOPERATIVE PROGRAM

Much of the weed and nematode control research in the Department is cooperative with State Experiment Stations, other Federal agencies, industry and certain private groups; and is cross commodity in nature. The total Federal weed control program involves 83.2 scientist man-years' effort. Of this total, 28.3 man-years are specifically directed to weed control in cereal crops and forage and range plants. The total Federal nematode control program involves 26.0 scientist man-years' effort of which 0.3 are devoted to cereals and 1.1 to forage and range crops. There are P.L. 480 projects at Poznan, Poland, to study the effects of chemical and mechanical control methods on weeds, corn, and associated crops and at Lucknow, Indiana, for biochemical studies on angiosperm parasites--dodder and witchweed; at Orissa, India, for nematodes attacking rice and at Jodphur, India, on nematodes attacking millets.

PROGRAM OF STATE EXPERIMENT STATIONS

The total State scientific effort devoted to weed control research is 143.3 scientist man-years and to nematode identification, physiology and control 47.3 scientist man-years.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Weed Control

1. Herbicide Physiology and Weed Control in Corn. In PL 480 research in Poland, several s-triazine herbicides, applied to susceptible plants, rapidly increased the content of free amino acids and decreased sugars other than glucose. Glucose content increased as effect on the plant increased. Action on less sensitive plants was similar, except that the rates of change were slower and that glucose content decreased also.

Substituted urea and s-triazine herbicides, applied at minimum rates necessary for control of weeds in corn, did not injure spring crops planted the next year after corn. Simazine and linuron inhibited the development of algae in the soil, but of the two, only simazine at high rates inhibited Collembola. Neither s-triazine nor substituted urea herbicides, applied at minimum rates required for control of weeds, had any adverse effects on corn under field conditions.

In North Carolina, several nitrogenous fertilizers, applied at a rate to provide 400 lb/A of nitrogen, provided effective control of witchweed and acceptable tolerance of corn. Sodium chloride provided effective control at 200 lb/A, but killed the corn when applied at 400 lb/A.

2. Grain Sorghum. In Kansas, the addition of small quantities of a highly refined emulsifiable oil to aqueous mixtures containing atrazine markedly improved the effectiveness for control of weeds in grain sorghum.

3. Rice. In Arkansas, Nova 66, a 130-day maturing variety of rice, competed better with barnyardgrass than either Bluebonnet 50 (150 days) or Bluebelle (110 days). The experimental herbicide, SD-11831, applied pre-emergence and irrigated, controlled barnyardgrass without injury to rice. Potassium azide applied postemergence in water-seeded rice controlled several aquatic weeds with only slight injury to the rice. However, it injured drill-seeded rice severely. Rice growing under stress caused by cool temperatures or adverse soil pH appeared more susceptible to injury than rice growing under optimum conditions. Potassium azide persisted longer in flooded soil than in moist; it persisted longer in soils with a pH of 6 to 7 than in those with a pH of 4 to 5. Potassium azide killed catfish and crawfish for several days after application, but did not injure catfish placed in treated plots 13 days after treatment. Several experimental materials including CP-31497, a copper salt of endothall, C-6989 and o-6K controlled blue-green algae without injury to rice.

4. Wheat, and Wheat-Sorghum-Fallow Rotations. In Kansas, long-term studies of a wheat-sorghum-fallow rotation indicate that maximum use of herbicides combined with minimum tillage causes a shift in weed species population from primarily broadleaf weeds to primarily weed grasses. Although the use of herbicides results in better weed control and higher yields, it now appears that some tillage is required for most effective crop production.

5. Vapor Activity of CIPC on Dodder in Alfalfa. Research in Washington strongly indicates that the herbicidal activity of CIPC against dodder is primarily from vapors emitted from the soil surface, or from the surface of herbicide granules. Evidently the CIPC does not need to enter the soil solution to exert its phytotoxic action, but can contact the dodder through the atmosphere.

6. Control of Dodder in Alfalfa with Dichlobenil. In Washington, surface applications of dichlobenil just before or just after irrigation controlled dodder effectively with minimum crop injury. Incorporating dichlobenil with the soil did little to increase the weed control effectiveness, but did increase alfalfa injury markedly.

7. Control of Weeds in Grass Crops Grown for Seed. In Oregon, bromoxynil applied at early growth stages in four perennial grass crops controlled annual broadleaf weeds with less injury to the grass crops than the currently recommended combination of dicamba-2,4-D. Picloram controlled Canada thistle without injury to tall fescue, chewing fescue, or orchardgrass. Split applications of diuron (fall and spring) controlled annual bluegrass much better than a single application in the fall, and did not interfere with seed production. October application of atrazine controls annual ryegrass and most other troublesome weeds in March or April seedings of perennial ryegrass without interfering with seed production, thus opening the way to production of quality seed of new perennial ryegrass varieties developed in foreign countries for increase and returned to the country of origin. Three species of grass were highly tolerant to picloram while four species were much less tolerant.

8. Weeds in Grazing Lands

Weed Competition. The main effects of weed competition in microenvironment within established alfalfa are directly related to the height and composition of the canopy developed. In Indiana, this is noted in the measurement of outgoing radiation, air temperatures in and above the crop, soil temperature, vapor pressure, and saturation deficits. Generally, the more open the canopy the closer the parameters become. The more complete the ground cover, the more outgoing radiation recorded and the lower the air temperature within the stand and soil temperature.

A pigweed leaf-area index of one reduces the entire visible spectrum penetration by over 95 percent. Pigweed competition in the seedling year is greater than giant foxtail as measured by alfalfa stand reduction, yield, crown diameter and rate of recovery after weed removal.

The Hy-Cal 180° percent pyrliometer, Model P-8405, is equal to or better than the standard Eppley 50 junction pyrliometer for the measurement of solar radiation. It has advantages in weight, size, accuracy, stability, response time, and ruggedness.

Plot size can affect some of the microenvironmental parameters in and above a stand of alfalfa. In plots 50'x50' or larger, there was no difference in outgoing solar radiation. There was little difference in

air temperature above alfalfa stands in plots 50' x 50' or 100' x 100' but the smaller plot had a higher temperature in the morning and a cooler temperature in the evening within the alfalfa stand. Soil temperatures in 25' x 25' plot size were higher than all other plot sizes studied. Humidity measurements have the greatest variability with the smaller plots having the greatest saturation deficits in the crop. Larger plots may have as much as 100 ppm higher CO₂ level in the crop at night. Almost all the variation due to plot size can be explained on the basis of border effect at any stage of stand development.

Thistle Complex in Nebraska. The seed germination responses to combinations of low temperatures and moisture were highly variable among eight species of thistles in 1965 and 1966. Cirsium discolor, C. vulgare, and C. flodmani usually did not respond significantly to cold treatments. Cirsium undulatum and Carduus nutans germinated better when given cold treatments. Scarification, acid treatment, and soaking in gibberellic and indole acetic acid failed to stimulate germination in Cirsium discolor. There was great variation in germination of Carduus nutans among samples collected at many locations in Nebraska.

More musk thistle seedlings became established in nongrazed, cool season grass pastures than in nongrazed, mixed warm season grass pastures. The cool season species, brome grass and intermediate wheatgrass, grow in more open stands than the warm season grasses or weed infested Kentucky bluegrass pasture. Most of the musk thistle plants that germinated in the protected areas in 1965 had succumbed to the heavy competition by 1966.

Musk thistle seed collected at various locations across the State of Nebraska were planted August 11, 1965, and the resulting plants flowered in June 1966. Some gross morphological variations were seen among the plants from different localities. Selfed and open pollinated progeny of these plantings were again planted in the nursery in August 1966. Also of interest, was a fairly rare white-flowered form of musk thistle that was found in Lancaster County associated with an infestation of normal musk thistle and scattered plants of plumeless thistle.

Rush Skeletonweed. Rush skeletonweed achenes become viable 4 to 5 days before dispersal and show no dormancy to blotter germination in Washington. The development period ranges from 11 to 15 days from flower opening. The average length of maximum hypocotyl elongation for the late flowering type is 6 to 7 mm longer than the earlier flowering type. Loss of seed viability after one year of burial in the soil ranged from 65 to 100 percent depending on depth of burial and whether the seed was from early flowering or late flowering type plants.

Wild Garlic. Embryonic shoots of all types of wild garlic bulbs usually elongate rapidly after dissection from the bulbs, except that they will not elongate for about one month after ripening in spring in Missouri. Microscopic studies show that embryonic shoots of wild garlic, even though in a state considered to be dormant, elongate slowly and gradually produce new leaf primordia.

Dormancy of False Hellebore and Larkspur Seeds. Dormancy was not broken in false hellebore and larkspur seeds held under snow in the forest when the seeds were not exposed to the unfrozen ground in Utah. Dormancy was shortened by 1/3, however, when the seeds were subsequently transferred to optimum conditions in the laboratory. Seeds of these species, when placed on the surface of unfrozen ground, but under the snow, germinated before the snow melted.

Timber Milkvetch. We have isolated the poisonous principle in timber milkvetch in pure form after separation in a counter-current distributor in Utah. Identification studies of the chemical are continuing.

Spring Parsley (*Cymopterus watsonii*). Physiological studies undertaken in cooperation with the Animal Disease and Parasite Division showed that the photoactive compound was present in the leaves and seeds and absent in the stems and roots. The compound is activated in the long-wave ultraviolet around 360 millimicrons. One-week-old chicks have proved to be excellent test "animals" for biological assay of this species in Utah.

One of the developments of our joint work has been the use of small chickens for bioassay. Already we have completed work dealing with the photosensitizing properties of spring parsley on chicks which would have required 200 sheep and an untold number of man-hours to collect and process enough plant material for test in large animals. In short, we have found that by using chicks for bioassay we could telescope into a single summer investigations important to both our animal and plant sciences which normally might have required several years had sheep been used. The cost of chicks versus sheep in terms of time, money, space, labor, etc. is extremely small. Many of the findings with chicks are applicable to live animals so that only final results need be confirmed with cattle and sheep.

Commercial Dehydrator Reduces Dalapon Residue Dalapon (2,2,-dichloro=propionic acid) was applied to alfalfa during May 1966 at 0, 2, 5, and 10 lb/A and chopped with a field chopper 2 weeks later in New York. Eight hundred-pound samples of each variable were passed through a commercial dehydrator-pellator. Approximately 75 percent of the dalapon was removed during this operation. Dalapon as the acid was assumed to have

volatilized during the heating operation. Little degradation per se was suspected.

9. Weed Control in New Seedlings. In Missouri, weed grasses were controlled without injury to seedling Coronilla varia L. with preplanting treatments with 3 lb/A EPTC (ethyl N,N-dipropylthiocarbamate), 1 lb/A trifluralin (alpha,alpha,alpha-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine), 1 lb/A benefin (N-butyl-N-ethyl-alpha,alpha,alpha-trifluoro-2,6-dinitro-p-toluidine), and 3 lb/A 64-296 (mixture of 1,1-dimethyl-4,6-diisopropyl-5-indanyl ethyl ketone and 1,1-dimethyl-4,6-diisopropyl-7-indanyl ethyl ketone). Postemergence treatments with bromoxynil (dimethylarsinic acid) and 2,4-DB (4-(2,4-dichlorophenoxy)-butyric acid), severely injured this legume.

Potential interaction of EPTC and DNBP (4,6-dinitro-o-sec-butylphenol), used for weed control during establishment of alfalfa and birdsfoot trefoil was studied in the field in New York. Interactions on stand and yield of legume were considered to be insignificant. Chemical effects were due to the chemicals acting alone rather than as synergists or antagonists. Also previous research regarding protective effects of charcoal applied in strips over rows of seeded alfalfa was verified in New York. Charcoal applied at 25, 50, and 100 lb/A protected alfalfa from adverse effects of the s-triazine herbicide G-36393.

Trifluralin, benefin and nitralin (4-(methylsulfonyl)2,6-dinitro-N,N-dipropylaniline), somewhat similar in their chemistry, were similar in herbicidal activity for weed control in establishment of alfalfa and other forage legumes. Nitralin was slightly more phytotoxic at doses equimolar to trifluralin or benefin in two Maryland soils. Benefin was least phytotoxic of the three. While the standard treatment of EPTC gave excellent initial control of weed grasses, residual activity was not sufficient to provide satisfactory season-long weed control. Benefin at 1 lb/A, trifluralin or nitralin at 1/2 lb/A, and EPTC at 3 lb/A were adequate for selective weed grass control in alfalfa if they were incorporated in the surface 2 inches of soil. Control of weed competition promoted an increased hay yield in the seedling year adequate to offset the cost of control only when final alfalfa seedling density was one plant per square decimeter. More than one seedling of alfalfa per square decimeter was required to adequately use the productivity of the weed-free plots.

10. Controlling Weeds in Humid Pastures. Fair to excellent control of bitter sneezeweed was obtained without serious reduction in stand of lespedeza with 1 and 2 lb/A of 2,4-D (2,4-dichlorophenoxyacetic acid) 1 lb/A of dicamba (2-methoxy-3,6-dichlorobenzoic acid) and 0.5 + 0.125 lb/A of

2,4-D + picloram (4-amino-3,5,6-trichloropicolinic acid) applied pre-emergence in Mississippi. Higher rates of picloram alone or with 2,4-D controlled the weeds but nearly eliminated lespedeza. Very similar results were obtained with sumpweed except in this test, dicamba reduced stand of lespedeza more than it had in the lespedeza trial. Postemergence applications of 0.5 and 1 lb/A of picloram or 1 + 0.25 and 2 + 0.5 lb/A of 2,4-D + picloram controlled yankeeweed or Eupatorium dog fennel 100 percent. Lower rates of picloram and of the mixture and 2,4-D and dicamba at 1 and 2 lb/A were much less effective.

Broomsedge in Mississippi pastures decreased in stand in established experiments where nitrogen fertilization had been combined with mowing and heavy grazing. After 3 to 4 years, broomsedge has almost disappeared. In new experiments, the first season results show a decrease in broomsedge stand, an increase in volunteer dallisgrass, an increase in production and consumption of forage, an increase in percent consumption of total vegetation or forage, and an increase in crude protein from nitrogen fertilization. All plots were mowed and grazed free choice. White clover plots were slightly better in all these respects than the checks, but inferior to nitrated plots.

In Missouri, bromoxynil applied postemergence on May 25 at 3/4 lb/A reduced yields of lanceleaf and common ragweed 93 percent and yields of lespedeza growing with the ragweeds increased 94 percent. Bromoxynil reduced yields of ragweeds to the same extent as 1 lb/A of 2,4-D amine but lespedeza treated with bromoxynil yielded 300 lb/A more than when treated with 2,4-D amine.

In mature birdsfoot trefoil, bromacil at 1 lb/A and atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) at 1 and 2 lb/A applied in March controlled Barbarea vulgaris, Erigeron spp. and Bromus spp.

11. Control of Weeds in Rangelands. In Washington, minimum herbicidal treatments for control of Dalmation toadflax included silvex (2-(2,4,5-trichlorophenoxy)propionic acid) at 3 lb/A or silvex + picloram, 2 + 1/4 lb/A, respectively. Dalmation toadflax has the ability to invade and kill out other perennial herbaceous species by competition for moisture and possibly by a toxic principle. Life of the primary crown of Dalmation toadflax averages about 3 years, survival beyond that time is dependent on the plants arising on lateral roots.

Bracken is killed by granular formulations of picloram and dicamba applied in the fall in northern Idaho. Western false hellebore in Utah can be controlled by spraying the foliage of the plants when the upper leaves are fully expanded and just before flower bud initiation by 4 lb/A of: the

amines or esters of 2,4-D, silvex or mecoprop (2-(2-methyl-4-chlorophenoxy) propionic acid); or a 1:1 mixture of 2,4-D and dicamba. Two treatments should be applied in successive seasons. Low larkspur was controlled with picloram, fenac (2,3,6-trichlorophenylacetic acid), dicamba, and 2,4-D in Utah. Picloram, dicamba, and 2,4-D successfully reduced big sagebrush and silky lupine. Treatments with these three compounds also resulted in significantly increased forage production by grass species. Treatments of rangeland with the herbicides should reduce cattle losses to low larkspur and calf losses to silky lupine.

B. Nematode Control

1. Forage and Range. In southern Utah, the organophosphate insecticide dimethoate, applied at 0.5 lbs/per acre to 3-6 inch high alfalfa, reduced the stem nematode, Ditylenchus dipsaci, from 2,579 nematodes per gram of crown-bud tissue to 92. The first alfalfa cutting yielded 1.41 and 1.63 tons per acre, respectively, for untreated and treated plots, representing a 13% increase in yield. The second cutting gave only 5% increase when environmental conditions were no longer suited to nematode damage. In cooperation with plant breeders at Auburn University, 37 lines of Senecio lespedeza were tested for root-knot susceptibility at Tifton, Georgia; backcrossing has increased levels of resistance in several lines (Auburn Entry No. 8 and No. 32). Several legume crops were evaluated at Tifton for resistance to root-knot nematodes in order to find possible new forage crops with resistance to the nematodes. The legumes Stizolobium deeringianum, Glycine javanica, Desmodium intortum, D. tortuosum, D. uncinatum, Stylosanthes humilis, Indigofera hirsuta, Cajanus cajan, Phaseolus stropunurus, Aeschynomene americana, Alvysicarpus vaginalis, and Dolichos lab lab were tested for susceptibility to Meloidogyne incognita incognita, M. incognita acrita, M. arenaria, and M. javanica. Velvetbeans (S. deeringianum var. Early Jumbo and Victor) were the only legumes resistant to all four species of root-knot nematodes. Glycines javanica (var. Tinavoo, Clarence, and Cooper) and Desmodium spp. were moderately susceptible to only M. arenaria. These crops should prove useful in root-knot nematode reducing rotations over a wide area. The other legumes had variable susceptibility to the root-knot species, but were especially susceptible to M. arenaria. Nematodes are frequently moved in inter- and intrastate shipments on grass sprigs and sod, frequently causing quarantine seizures or spread of nematodes. Tests at Tifton proved that Bermudagrass sprigs can be freed of nematodes by hot-water dips of 55°C for 15-40 minutes, without injury to the grass. Such a treatment should aid in freeing sprig shipments of nematodes.

2. Grain. Root-knot nematodes recently have been found associated with grain sorghum on the High Plains of Texas. The nematodes that increase on

sorghum subsequently do great damage to cotton in that area. Field experiments at Lubbock show that nematocide treatment of grain sorghum increase yields 15-25% (780 and 960 lbs/acre) in two field tests where cotton root-knot nematodes were controlled, indicating the potential of nematodes in limiting grain sorghum production as well as posing a problem for subsequent crops of cotton. Thirty breeding lines of grain sorghum were tested at Lubbock for susceptibility to the cotton root-knot nematode; best plant growth and lowest root-knot infections was for Punnels #11 Broomcorn, and PL 35038 Sumae; in all other lines and varieties tested, root-knot reduced grain sorghum growth by as much as 44 percent.

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CORN SORGHUM, AND SMALL GRAIN INSECTS
Entomology Research Division, ARS

Problem. Many species of insects cause losses amounting to millions of dollars annually to corn, sorghum, and small grains. It is estimated that 25 species of insects cause an annual loss of \$900 million to corn alone. The European corn borer and corn earworm are two of the most destructive insects in the country, and corn rootworms are serious pests of corn. Armyworms attack corn and small grains. In certain years the greenbug causes widespread losses to wheat, barley, and oats in the Central and Southeastern States, and the Hessian fly and wheat stem sawfly annually damage the wheat crop in certain areas. The cereal leaf beetle, first identified in the United States in 1962 from Berrien County, Mich., now occurs in many counties in Michigan, Indiana, Illinois, Pennsylvania, and Ohio, and is a threat of unknown proportion to small grain crops. Such examples of the destructiveness of insects to corn, sorghum, and small grains point up the need for extensive research that will lead to the development of adequate means for the control of these important crop pests. Progress has been made toward the solution of some of the insect problems encountered in the production of grain crops but more effective, more economical, and safer insect control measures are needed. Research is essential to find insecticides that can be applied to grain crops, that will not leave residues harmful to animals consuming the feed, that will not be a hazard in milk, and meat, and that will not be detrimental to beneficial insects or to fish and wildlife. The appearance of resistance to certain insecticides in several grain insect pests stresses the need for basic information to overcome this problem. Additional emphasis should be placed on research to develop crop varieties resistant to insects and on biological and cultural control methods. New approaches to insect control, such as sterilization techniques and attractants, require expanded investigation. Research is also needed on insect vectors and the role they play in the dissemination of important plant diseases. The heavy losses in oats, wheat, and barley due to barley yellow dwarf virus, and in corn due to maize dwarf mosaic and corn stunt recently found in several North Central and Southern States, indicate the importance of research in this field.

USDA AND COOPERATIVE PROGRAM

The Department's program involves both basic and applied research directed toward developing more efficient control methods for insects attacking grain. All studies are conducted in cooperation with State Experiment Stations in the several States where research is underway. Studies on evaluating and developing varieties of grain which resist insect attack are conducted in cooperation with State and Federal agronomists and plant breeders and research on insect transmission of diseases of grain crops is in cooperation with State and Federal plant pathologists. This research includes studies on Hessian fly at Lafayette, Ind., and Manhattan, Kans.; cereal leaf beetle at Lafayette, Ind., and East Lansing, Mich.; aphids and

mites attacking small grains at Stillwater, Okla., Brookings, S. Dak., and Tifton, Ga.; wheat stem sawfly at Fargo, N. Dak., and Bozeman, Mont.; corn earworm at Tifton, Ga., State College, Miss., and Lafayette, Ind.; fall army-worm, pink scavenger caterpillar, and rice weevil at State College, Miss., and Tifton, Ga.; soil insects attacking corn at Brookings, S. Dak., State College, Miss., and Tifton, Ga.; corn leaf aphid at Brookings, S. Dak.; southwestern corn borer at State College, Miss.; European corn borer at Ankeny, Iowa, State College, Miss., and Wooster, Ohio; corn earworm, sorghum midge, sorghum webworm, and corn leaf aphid on sorghums at Stillwater, Okla., and Tifton, Ga.; and insect transmission of grain diseases at Wooster, Ohio, State College, Miss., and Brookings, S. Dak. Research to evaluate improved equipment for application of insecticides to grain crops is underway at Ankeny, Iowa, and Tifton, Ga., in cooperation with Federal agricultural engineers. Work on corn rootworms is being conducted at Brookings, S. Dak. Research on insects attacking the major cereal grains in Africa is being conducted under U.S. AID Contract in Zaria, Nigeria, and Serere, Uganda. Additional research is being conducted under ARS contracts and grants on the biology and control of the cereal leaf beetle with Michigan, Indiana, and Ohio Experiment Stations, and vectors of corn stunt virus with Mississippi State University, nature of resistance of corn to the European corn borer with Iowa State University. Nature of resistance of small grains to greenbug with Oklahoma State University, and nature of resistance of corn to corn earworm with Missouri University and insect communication in the infrared region with Michigan University, Ann Arbor, Mich.; University of California at Berkley, and Georgia Tech at Atlanta, Ga.; transmission of viruses causing stunting of corn, with Missouri University and Ohio University, and ecological factors affecting efficiency of Trichogramma spp. with Louisiana State University.

The Federal scientific effort devoted to research in this area totals 43.3 scientist man-years. Of this number 10.8 is devoted to basic biology, physiology, and nutrition; 3.5 to insecticidal and cultural control; 1.8 to insecticide residue determinations; 4.1 to biological control; 2.9 to insect sterility, attractants, and other new approaches to control; .5 to evaluation of equipment for insect detection and control; 15.7 to varietal evaluation for insect resistance; 2.8 to insect vectors of diseases; and 1.4 to program leadership.

Certain phases of this research are contributing to regional research project NC-87 "Studies of the biotypes of the European corn borer." A P.L. 480 project, A10-ENT-5, "Host Plant-Vector and Host Plant-Virus Relationships of Rough Dwarf Virus of Corn and Methods for Control of the Disease" is being conducted at the Hebrew University, Rehovoth, Israel. A7-ENT-25 in India is concerned with "Research on Insect Pests of Maize with Special Reference to Stalk Borers." Projects A7-ENT-31 in India, Investigations on insect pests of sorghum and millets," E21-ENT-14, in Poland, "Studies Regarding the Bionomics, Economic Importance and Natural Control Factors Affecting Oulema Species (Cereal Leaf Beetle) in Poland," and E30-ENT-3 in Yugoslavia on "Parasites, Predators, and Pathogenic Organisms

Study of the Cereal Leaf Beetle and Resistance of Domestic and Foreign Small Grain Varieties to the Insect, are also being conducted.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 37.7 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Corn Insects. Ecological data on the European corn borer at Ankeny, Iowa, showed the following populations per acre: early spring 3,042, late spring 975, midsummer 1,854, and postharvest 6,271.

Field experiments investigating the possible existence of biotypes of the European corn borer were continued at Ankeny, Iowa. Borer populations from seven geographic areas, on three host types were studied. Results showed that the Minnesota and Missouri borers differ distinctly and Iowa was intermediate in several ecological characteristics. It was also shown that the biology of each biotype is influenced by the ecological conditions such as location of the experimental plot and host variety. Comparing the diapause of the seven populations, the percent diapause for first generation borers seemed to increase with the northern latitude of the origin of the population.

Laboratory data at Ankeny has shown that corn pollen is important in the nutrition of young European corn borer larvae. Field data showed that pollen was important for good establishment of second-brood larvae on susceptible inbreds, but had no effect on the establishment of the larvae on resistant inbreds.

Satisfactory methods have been developed at Ankeny for rearing European corn borer on artificial media. However, conflicting field data on the level of establishment of their offspring on inbred lines of corn compared with those of field-collected moths have been obtained. In 1966 establishment on susceptible inbred WF9 by larvae from parental stock reared continuously (30+ generations) on the artificial diet was at a low level compared with larval establishment from a field-collected population. It is not unreasonable to assume that larvae reared on an artificial diet for many generations may become so acclimated to the diet that they no longer prefer corn as host plant.

At Wooster, Ohio, mass selection of a strain of nondiapause corn borer for seven generations has increased the incidence of nondiapause in an Ohio population from 16 to 88%.

Gossypol mixed in the diet was significantly toxic, reduced larval and pupal weight, and increased the time to pupation at the lowest rate tested

(0.10%). This percentage is much lower than that found in many commercial glanded cotton foliage.

The southwestern corn borer continues to spread and was found in one additional county in Mississippi, two in Alabama, four in Tennessee, and eight in Kentucky in 1966. This was the first record of the borer in Kentucky.

A satisfactory laboratory technique for rearing the southwestern corn borer has been developed at State College, Miss.

In Mississippi second generation southwestern corn borer females were dissected to determine the percent mated. Mating was determined by the presence of one or more spermatophores. Of those mated 70% had one spermatophore, 19% had two, 10% had three, and 1% had four. This indicates that this insect will often mate more than once.

At Tifton, Ga., work has been progressing in plotting the various sensors on the antennae and the legs of the corn earworm moth. In a detailed study of the morphology of the antenna, 14 separate and distinct types of sensors have been located. These sensors have been plotted both with respect to the numbers present and to their physical configuration on the antennae. Electrophysiological work has shown that one sensor, the scape and pedicel dome sensor, of the noctuid and saturnid antennae responds to visible radiation.

At Tifton, Ga., data for the oxygen consumption of the larval and pupal stages of the corn earworm were obtained. On the basis of microliters per milligram per hour the pupae exhibit a typical U-shaped curve, while larval curve is inversely related to total weight.

Winter mortality of the rice weevil was studied at four locations in Mississippi. Mortality of the immature stages inside the corn kernels showed a definite increase progressing northward, Poplarville, the southernmost location, averaged 18.2% mortality, Newton 34.2%, State College 48.2%, and Holly Springs 56.3%. These results seem to be correlated with lower temperatures and moisture content of the grain at the northern locations.

At Tifton, Ga., the mass production of fall armyworm and corn earworm to be used in research has continued. The casein-wheat germ diet, regularly used for rearing corn earworm, has been replaced with a less expensive pinto bean diet. The bean diet has been satisfactorily modified to shorten length of time required for pupation and to obtain a more uniform rate of pupation.

A survey to determine population levels of the corn earworm, fall armyworm, and sugarcane borer is underway on St. Croix, U. S. Virgin Islands. Results show that all three species are firmly established on St. Croix.

Definite population peaks of the fall armyworm and corn earworm occurred in early May and early to mid-June. Infestations of the sugarcane borer are confined to the central portion of the Island where sugarcane fields exist. Additional data pertaining to alternate host plants and levels of parasitism are being collected.

Studies initiated at Tifton, Ga., were conducted to determine if the fall armyworm overwinters in the Southern States. None were collected in traps placed along roadsides between Tifton, Ga., and Baton Rouge, La., during the last week of March, but moths were collected at Houma, La., during the first week of May. In Mississippi fall armyworm males first appeared May 4 in Poplarville, June 1 in Newton, May 12 in State College, and May 25 in Holly Springs. Fall armyworm males were collected on April 24 in Tifton, Ga. These data indicate that the fall armyworm may have survived the mild winter of 1967 and overwintered along the Gulf Coast.

The northern and western corn rootworms have been reported as being host specific for corn. However, laboratory and field tests at Brookings, S. Dak., have shown conclusively that these insects can complete their life cycle and produce fertile adults when reared on certain varieties of wheat and barley and a number of the grasses common to the Midwest.

Simple maze devices have shown that the larvae of the western corn rootworm are attracted to the roots of their primary host, corn, and to a non-host, cultivated oats. The reason that oats is a nonhost is therefore apparently not due to the presence of a repellent nor to the lack of an attractant. Larvae of the western corn rootworm maxillectomized with a small laser beam and placed on oat roots lived longer than normal larvae. This may indicate that oats lacks a feeding stimulant usually sensed by a normal larva.

2. Small Grain and Sorghum Insects. Survival and reproduction of four species of aphids under three types of filters were studied at Brookings, S. Dak. Colored cellophane filters had negligible influence on aphid performance, probably because they transmitted across the visible range and differed little in their spectral transmission. Colored Wratten filters, however, had a pronounced effect on aphid performance. The English grain aphid, greenbug, and corn leaf aphid survived longer and reproduced more under a yellow Wratten filter. The apple grain aphid survived longer under a green filter. In general, cereal aphids performed best under the same color they chose in preference tests. Color preferences of adults and nymphs of the four aphid species were tested under controlled conditions in the laboratory. Adults and nymphs of apple grain aphid and nymphs of corn leaf aphid preferred green over yellow, red, or blue. Adults of corn leaf aphid, and adults and nymphs of English grain aphid and greenbugs preferred yellow over other colors available.

In studies at Brookings, S. Dak., false wireworm adults, Embaphion muricatum, were given choices of seeds of several common crops and grasses.

Seeds showing the highest rate of feeding included alfalfa, hulless oats, rye, sand lovegrass, sweetclover, and wheat. Corn, forage sorghum, grain sorghum, green foxtail, hulless barley were moderately preferred. Many seeds showed little or no feeding by the beetles even when other foods were denied them. These included barley, big bluestem, bluegrass, bromegrass, crested wheatgrass, flax, green needlegrass, Indiangrass, little bluestem, oats, Russian wild rye, sand bluestem, side-oats grama, soybean, sudan grass, sugar beet, switch grass, western wheatgrass, and yellow foxtail.

A species of false wireworm, Eleodes obsoleta, was reared on ground wheat in the absence of soil in the laboratory. It was found to have nine larval instars. The length of the larval period averaged 133 days, the prepupal period 6.8 days and the pupal period 19.9 days or an average life cycle of 159.7 days. If the life cycle were the same length in the field, this species would have only one generation per year in South Dakota. As a part of the studies to clarify the biology and ecology of false wireworms, pitfall traps were set in wheat fields throughout South Dakota in three general types of soil to determine the distribution of various false wireworm species. The preference of nine species of false wireworms was correlated with three basic soil types. All species except one were much more plentiful in the semi-arid portions of the state.

A census of wheat stem sawfly populations in 20 counties of western North Dakota was conducted in the fall of 1966. Percent fields infested per county ranged from 100 to 12%. Greatest damage from sawfly stem cutting occurred in the northwestern counties. Greatest damage from sawfly stem tunneling occurred in the southwestern counties. This census assisted Experiment Station workers in equitably distributing seed of the newly released sawfly resistant variety, Fortuna, to growers in the western half of North Dakota.

At Lafayette, Ind., studies of the racial composition of field populations substantiate the apparent buildup of Race B populations of Hessian fly in Indiana where resistant varieties having the resistant H_3 gene have been grown since 1955. Race B was the predominant race in nine populations collected from areas of previously infested W38 resistant fields. Although much less prevalent, but possibly more important, was the high frequency of Race D individuals. This race can infest both the wheats having H_3 and H_6 genes for resistance, making it desirable that varieties having the H_5 gene be released in the near future. Race A was still the predominant race in three populations collected from previously infested non-resistant fields although Race B was present in large numbers.

Progeny tests of a population from the hard wheat region in western Kansas showed the Great Plains race to be predominant with Race A occurring only at a low frequency. However, in a population from northeastern Kansas near the eastern edge of the soft wheat region, Race A was the predominant race. The Great Plains race occurred at a fairly high frequency and Races B and C occurred at a low frequency.

Genetic studies of the Hessian fly have shown that the inability of the Great Plains race of Hessian fly to infest wheats grown in the eastern soft wheat region is dominant to the ability of Races A, B, C, and D to infest these same wheats. First generation progenies, from reciprocal mating between individuals of the Great Plains race and Races A, B, C, and D, die on wheats grown in the eastern soft wheat region, including such historically susceptible varieties as Trumbull and Vigo.

Other studies involving reciprocal matings between individuals from Races A and B have shown that the inability of Race A to infest wheats having the H_3 gene for resistance is dominant to the ability of Race B to infest these same wheats.

Inheritance studies involving the Great Plains race and Race A and Races A and B have definitely shown that there is chromosomal elimination of paternally derived chromosomes during spermatogenesis resulting in only one functional sperm, having only maternally derived chromosomes.

Studies at Stillwater, Okla., on flight habits of aphids showed that they fly in every month, but heaviest flights were recorded during September, October, November, and December and in the spring months of March, April, and May.

Observations on sexual behavior of the cereal leaf beetle at East Lansing, Mich., indicated an absence of courtship prior to mating but some manifestations on the part of the male have been observed after mating. Time of actual copulation ranges from 4 to 121 minutes, with a time lapse between the end of copulation and separation of the male and female. Laboratory studies revealed a marked effect on oviposition behavior when adult cereal leaf beetles are exposed to 16 hours of light as contrasted to 8 or 24 hours. Oviposition is obtained after as little as four weeks of cold storage when beetles are kept in a 16-hour photoperiod whereas as much as 16 weeks of storage is needed before oviposition occurs under the other photoperiodic conditions. Under laboratory conditions some virgin female cereal leaf beetles were capable of ovarian development and oviposition when exposed to a 16-hour photoperiod following a minimum of 12 weeks of cold storage. Eighty percent of the virgin females developed ovaries and an average of four eggs per female were deposited when the insects were confined under lantern globe cages over potted barley. No embryonic development occurred in the eggs obtained from these females.

Laboratory studies indicated the possibility that only the female cereal leaf beetle has an obligatory diapause. Mating and oviposition does not normally occur until after the female has been in diapause and is subsequently exposed to proper photoperiodic conditions. However, when pre-diapause males are placed with virgin post-diapause females under suitable conditions, mating and oviposition occur in the same manner as when post-diapause males are used.

Attempts have been made to isolate a non-diapausing strain of cereal leaf beetle. However, no detectable strain has been found to date.

Diapause in the adult cereal leaf beetle was effectively terminated by topical treatment with the synthetic juvenile gonadatropic hormone, trans, trans, 10, 11, epoxyfarnesenic acid methyl ester. Subsequent work has indicated that only the females need be treated.

Studies in Zaria, Nigeria, showed three major pests of sorghums. These are the shoot fly, stem borers, and the sorghum midge. Information has been obtained on the biology of these insects.

B. Insecticidal and Cultural Control

1. Corn Insects. At Ankeny, Iowa, eight systemic insecticides were evaluated for European corn borer control. American Cyanamid CL-47470 (4 pounds per acre), Niagara NIA-10242 (2 and 4 pounds per acre), ENT-27396 (2 pounds per acre, Bay 39007 (2 pounds per acre), and ENT-27389 (1.5 pounds per acre) gave encouraging results. More than 25 insecticides were tested against first-generation borers at various rates and mixtures. Phorate, CL-47470, diazinon, Dursban, Niagara NIA-10242, Stauffer N-2790, EPN, ENT-25 15-d, and ENT-27396 were as effective as DDT. Twenty-two insecticides were evaluated for control of second-generation borers. Dursban, diazinon, EPN, ENT-27320, ENT-27392, and a mixture of parathion and endrin were outstanding at the rates tested.

Three experiments were conducted to examine any effects that row widths of 20, 30, and 40 inches and plant populations of 13, 17, and 26 thousand plants per acre might have on the establishment of artificial infestations of the borer and control on field corn with granular insecticides. No differences were indicated in establishment of first-generation borers. Granules applied on the basis of foot of row per acre resulted in no significant differences due to row width, plant population, or the interaction of these for first- and second-generation borers.

Two experiments on 20 inbred and 30 single cross corns to examine the effect of visible phytotoxicity resulting from the application of diazinon on total yield, seed weight, and test weight were conducted. Differences of foliar response between entries were evident but this was not reflected by yields.

In Mississippi, Niagara NIA-10242 granules (5%) at 1.0 pound per acre per application as a soil systemic insecticide did not significantly reduce southwestern corn borer damage in dent corn in tests at two locations. Foliar treatments of endrin, endosulfan, and NIA-10242 at 0.5 pound per acre per application significantly reduced southwestern corn borer damage when two applications per generation were applied for the second and third generations. Two applications of Azodrin per generation at 1.0 pound per acre per application, applied as a spray in the whorls of the plants, showed potential in controlling the borer.

Several experimental compounds were effective in controlling fall armyworms in laboratory experiments in Tifton, Ga. ENT-27449, 27386-a, 27448, 27409, and 27408 gave 100% mortality of third instar fall armyworm larvae in 24 hours.

In laboratory tests at Tifton fall armyworms were fed leaf discs treated with varying quantities of Azodrin and pp'-DDT. Azodrin was as effective as DDT in controlling third instar larvae. Control of the corn earworm and fall armyworm in field plots of sweet corn was significantly better with one pound per acre Azodrin than with two pounds per acre DDT.

At Brookings, S. Dak., aldrin resistant corn rootworm beetles absorbed topically applied aldrin and dieldrin more rapidly than the susceptible insects. However, the concentration of insecticides in the resistant insect remained relatively constant after absorption at about 50% of the applied 1 µg per insect dose as a result of excretion of both aldrin and dieldrin. Relatively low amounts of aldrin and dieldrin were excreted by the susceptible insect. Susceptible insects converted no dieldrin to aldrin whereas the resistant populations converted a sizeable quantity of dieldrin to aldrin. Both aldrin susceptible and resistant strains converted aldrin to dieldrin at about the same rate. Aldrin and dieldrin appear to be the only metabolites found in the treated insects.

2. Small Grain Insects. In tests at Bozeman, Mont., no insecticides have been found more effective against wheat stem sawfly than heptachlor in furrow applications. The additive, dimethyl sulfoxide (DMSO), used with oxydemetonmethyl in a foliage application gave control equal to that of heptachlor in a furrow application.

In integrated control tests for cereal aphids at Brookings, S. Dak., the LD₅₀ values of malathion for the insect predators of cereal aphids and the English grain aphid in South Dakota such as lady beetles, nabids, and lacewing flies, indicated that all insect predators tested were less vulnerable to the insecticide than the aphid. Predators escaped significant mortality after feeding on malathion-poisoned aphids treated topically at the same dosage levels as in the contact toxicity studies with predators. The potential for integrated control of cereal aphids with selected dosages of malathion appears promising. Similar tests with parathion, in the preliminary stage, have indicated that parathion is 20 to 30 times more toxic to adults of lady beetles and lacewing flies than malathion. The toxicity differential for the English grain aphid does not appear to be as great.

At Stillwater, Okla., further insecticide phytotoxicity study tests demonstrated the differential reaction among sorghums to insecticides. Grain sorghum variety OK 612 was severely burned by sprays of Bidrin and methyl parathion, but there was no damage to variety RS 610. There was no damage to either variety when sprayed with diazinon. In studies conducted to determine the cause of phytotoxicity to susceptible sorghums when sprayed with Bidrin, first injury appeared around stomata. Then there was shrinkage

and disintegration of the chloroplasts. Breakdown of the chloroplasts and the cells caused the tracheary elements to become filled with polysaccharide material. After 48 hours following spray application the entire leaf was dead.

At Zaria, Nigeria, carbaryl gave satisfactory control of sorghum stem borers.

Technical liquid disulfoton applied as a seed treatment on Rogers barley and Cimarron oats at rates of 16, 8, 6, 4, and 2 oz per 100 pounds seed resulted in 100% control of greenbugs at all rates up to 24 hours, but after 144 hours with reinfestation, there was little residual toxicity. On Ponca wheat control was 82% with the 16-oz rate of application, but it was ineffective at lower rates. On the basis of these tests it is not believed that liquid disulfoton would be effective as a seed treatment for wheat without use of stickers, but it would be effective for barley and oats for a short period. Greenbugs were effectively controlled by spray applications of Azodrin, disulfoton, GC-6506, and Dursban. Fourteen days after treatment all materials at all rates were still giving 90% control. Experimental compound ENT-27398 gave less than 50% control at the .5-pound per acre rate. The effective chemicals resulted in a 5-1/2 bushel per acre increase in wheat yields over yields of unsprayed checks.

A heavy chinch bug infestation developed early in the spring of 1967 in a field of Will barley seeded in a sorghum stubble field. Parathion, Bay 39007, dimethoate, disulfoton, toxaphene, and diazinon were applied at the rate of .4 pound per acre and carbaryl WP at 1-1/2 pounds actual toxicant per acre. Best control was obtained with parathion and carbaryl WP. Yields were increased 18.7 bushels and 10.3 bushels per acre over unsprayed checks.

At East Lansing, Mich., spray programs designed to suppress adult cereal leaf beetle populations were evaluated from an integrated control approach. Blanket spray programs using an ultra low volume application of malathion at 4 oz per acre were superior to selective field spraying of the same dosage for adult beetle control. However, time of application is a critical factor.

In research conducted under cooperative agreement at East Lansing, excellent protection of spring seeded oats was obtained under condition of high cereal leaf beetle populations through the use of a seed treatment of Bay 39007 at 1, 2, 4, and 8 ounces per 100 pounds of grain. Seed treatment with Niagara NIA-10242 and Union Carbide UC-21149 have also given good control.

C. Insecticide Residue Determinations

1. Corn Insects. Chemists at Tifton, Ga., developed gas chromatographic methods for analyzing Azodrin and Bidrin. The methods employ the melpar

flame photometric detector with the 526 mμ interference filter. Samples are blended with chloroform and the raw extracts are analyzed with no further cleanup necessary. Recoveries from sweet corn spiked with Azodrin (0.05-5.00 ppm) prior to extraction were better than 95%.

Residues of DDT-malathion, applied at 0.4 and 1.6 pounds per acre, respectively, were determined on plants after each of five application dates and at harvest time. After each of the five applications, residues ranged from 4 to 25 ppm. Residues on plants averaged 6.25 ppm DDT and 0.82 ppm malathion at harvest time.

A spectrophotofluoremetric (SPF) method was developed at the Tifton laboratory (in cooperation with Beltsville, Md., and Ankeny, Iowa, laboratories) for the analysis of 6-methoxybenzo-xazolinone (6-MBOA) in corn. This method has now been used to provide supplementary information on various lines of corn previously evaluated by several biological and chemical techniques.

D. Biological Control

1. Corn Insects. Studies at Ankeny, Iowa, showed that the nematode DD-136 was not effective in controlling the corn borer in the field, although it did kill larvae, pupae, and adults in the laboratory. Applications of 25,000, 50,000 and 100,000 nematodes per square foot of oat-seeded corn stalk debris failed to give control of the overwintering corn borer larvae. It appears that field conditions were such that the nematodes were not able to reach the borers in the corn stalks.

Bacillus thuringiensis applications in Iowa gave good results in the laboratory but were not as successful in controlling the borer in the field as in previous years. One explanation of this could be the lower viable spore counts and the difference in formulation of the products compared with past preparations.

Perezia pyraustae infection in European corn borer has been low in the Boone County, Iowa, study area for the past year but a slight increase was observed in the spring of 1967. In March 9% of the borers were infected and in April 18% were infected.

Preliminary laboratory tests using a new formulation of Thuricide against the southwestern corn borer in Mississippi have shown some control potential.

At Lafayette, Ind., quantitative studies with the fall armyworm nuclear polyhedrosis virus indicate an LD₄₅ for fourth instar fall armyworm of 2.66×10^8 polyhedral inclusion bodies. These values are much higher than the LD₅₀ values reported for fourth instar cabbage loopers treated in the same manner with cabbage looper nuclear polyhedrosis virus. Efforts are underway to determine why the fall armyworm virus is less effective and to increase its effectiveness.

Stored corn from Poplarville, Miss., and Baton Rouge, La., was examined for possible parasites of the rice weevil. Three species have been collected and were identified as Anisopteromalus calandrae, Habrocytus cereallae, and Zeteticontus sp.

Non-inclusion virus-like particles (150 X 500 mμ) were detected in fat bodies of four species of adult Carabid beetles which are predators of corn rootworms. Disease insects exhibit a distended abdomen. The hemolymph has a chalky-white appearance which could be caused by "free virus" particles. In ultrastructural studies, only the cytoplasm of the fat body is infected. Cell nuclei do not appear to be invaded. Each particle consists of a dense homogenous core bounded by a double membrane.

2. Small Grain and Sorghum Insects. Collyria calcitrator, a parasite of the wheat stem sawfly was released in infested fields in Montana. Some parasites were caged on wheat with the sawfly, wheat plants collected in the fall and inhabiting insects reared from them. One male C. calcitrator was obtained in this test, but none have been recovered from field releases.

A native parasite, Bracon cephi, is an important factor in controlling the wheat stem sawfly in portions of North Dakota. Evidence supporting the conclusion that this parasite is effective throughout the larval developmental period of the sawfly was obtained. Resistance or susceptibility of wheat varieties to the sawfly influenced both sawfly and parasite numbers. The parasite is more efficient at lower sawfly densities in resistant varieties than at higher sawfly densities in susceptible varieties.

A survey of the parasites of the wheat stem maggot fly, Meromyza americana, infesting wheat, rye, barley, and quackgrass in South Dakota showed the following parasites to be present: B. meromyzae, Coelinidea meromyzae, C. ferruginea, Bubeckia fallax, Eupelmus allynii, and Amblymerus spp. Parasitism ranged 17 and 28% in wheat down to 3% in barley. Emergence of parasites varied significantly with geographic area.

Approximately 75,000 egg parasites, Anaphes flavipes, of the cereal leaf beetle have been released at three locations in Michigan. Percent parasitization has not yet been determined but parasitized eggs have been found 40 feet from one release point and 60 feet from another.

Studies at Stillwater, Okla., indicated that spiders may be of considerable economic importance in controlling insects infesting sorghums. Several spider species which were considered as being the most important in this respect were used in laboratory feeding and mass-rearing studies. They feed readily on a large number of larval and adult insect forms, and techniques have been developed for obtaining viable eggs. Spiders were taken from a Johnson-Taylor suction trap mounted on a 40-foot-high building during every month of the year. The collection of the "ballooning" spiders throughout the year is further evidence of their possible importance

as biological control factors. Also, they are present in fields from the time plants emerge from the soil until the crops mature. Their populations increase as the size of the plants increases and as insect populations increase.

Research conducted under a P.L. 480 project has shown that there are several parasites of the cereal leaf beetle in Poland. Cultures of one parasite, Tetrastichus julis, is available to send to the United States.

In research conducted under a P.L. 480 project in Yugoslavia, an egg predator, Nabus feriodes, was found that destroys more than 50% of the cereal leaf beetle during the early part of the season. The egg parasite, Anaphes flavipes, destroys eggs during the later part of the oviposition period. A shipment of this species has been received in the United States and releases have been made.

In studies conducted at Purdue University on cereal leaf beetle parasites under a cooperative agreement, laboratory cultures of three larval parasites, Lemophagus, Tersilochus, and Tetrastichus, have been established and rearing procedures have been developed for the cereal leaf beetle egg parasite, A. flavipes.

In studies conducted under a research grant at Columbus, Ohio, no diseases have been found of the cereal leaf beetle which show promise for control. A fungus, Beauveria bassiana, was found in laboratory cultures. Unidentified intra-cellular bodies have been found within the adipose tissue which may be due to degeneration of normal cellular constituents resulting from inadequate nutrition.

E. Insect Sterility, Attractants, and Other New Approaches

1. Corn Insects. At Ankeny, Iowa, seven-day-old European corn borers were fed media containing tepa and adult males which developed from these larvae were sterile, but mating of the tepa treated ones was reduced.

In studies at Ankeny, Iowa, on the biochemical nature of natural resistance of corn to the European corn borer, it has been shown that the compound 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one is an effective feeding deterrent for larvae of the European corn borer. The conclusion seems clear that this compound is a major factor in the natural resistance of corn to the European corn borer. Chemically related compounds, 2,4-dihydroxy-1,4-benzoxazin-3-one, 2-hydroxy-1,4-benzoxazin-3-one, 2-hydroxy-7-methoxy-1,4-benzoxazin-3-one, and 2-O-glucosyl-7-methoxy-1,4-benzoxazin-3-one have also been found in corn tissue. These compounds are present in seedling plants throughout the development of the plant. Bioassay tests with the European corn borer have shown that N-OH benzoxazinones exert an antibiotic effect upon the borer, while N-H benzoxazin-3-ones have no apparent physiological effect on the insect.

A sex pheromone of the European corn borer has been isolated from the female adult. The pheromone functions as a sex stimulant to the male insect. The pheromone appears to play an important role in reproduction of the European corn borer.

Studies at Ankeny, Iowa, on the irradiation of diapausing larvae of European corn borer have shown that pupation, moth emergence, and mating were nearly normal at levels of irradiation as high as 5000 rads. Egg hatch and numbers of eggs laid were most severely affected at 4000 and 5000 rads.

At Tifton, Ga., mating studies in which tepa-sterilized and fertile fall armyworm males were mated to normal females show that the sequence in which the matings occur is very important. Females, mated to a sterile male and then to a fertile male, oviposited 95% viable eggs, indicating that sterile sperm are not competitive with viable sperm. However, in the opposite mating sequence, results were not so clear. Oviposition from females mated to fertile males and then sterile males indicate an all or nothing type response. Approximately 45% of the females produced all sterile eggs after the second (sterile) mating while 45% produced all viable eggs.

At Tifton, immersion of fall armyworm pupae in a solution of tepa containing varying quantities of acetone sterilized some of the emerging moths, but 100% sterility was not obtained with any of the treatments. A marked reduction in egg-hatch occurred in practically all treatments, with a marked increase in mortality of pupae and emerging moths. Other studies were conducted in which larvae of the fall armyworm were reared on media impregnated with varying amounts of tepa. A toxic effect was noted in concentrations greater than one-tenth percent with an occasional sterile response in some of the lower dosages. The major response was mortality of the larvae and adults in some cases, indicating a toxic rather than sterilizing effect of the material. Nonsignificant differences were noted in the effect on the males versus females.

In the combination light trap-chemosterilizer studies at Tifton increasing the concentration of tepa to 0.6% increased its effective time, both in the wick and the reservoir, to beyond five days, indicating that this may be a technique for increasing the overall effectiveness of the feeder. However, laboratory experiments indicated that when the material was used at a concentration higher than approximately 0.5%, the tepa acted as a feeding repellent to the adult and they only fed whenever forced to through starvation. However, laboratory experiments indicated that some but not all fall armyworm would be sterilized when passing through the feeder.

Studies with the light trap-chemosterilant feeder were conducted with the corn earworm in Georgia and the effects of 0.15, 0.3, and 0.6% tepa solutions on field-collected earworms were recorded. The 0.15% solution

reduced but did not eliminate egg hatch in all instances when the material was held for as long as seven days in the field and bioassayed after each 24-hour period. The 0.3 and 0.6% concentrations reduced egg hatch and oviposition. Some increases were noted in mortality for each of the treatments, indicating that the material is toxic to corn earworm in higher concentrations.

A cooperative agreement with Auburn University, in which the sex attractant of the southwestern corn borer will be studied, is under way. More than 10,000 virgin females have been reared, abdomens clipped, and sent to Auburn for study.

Results of laboratory tests at Tifton, Ga., using excised corn leaf segments as a substratum indicated that an attractant made from a water extract of corn kernels mixed with the insecticide, Shell SD-8447, used at the rate of 0.5 ounce of active ingredient per 25 gallons of water, increased earworm larval mortality approximately 30% above that obtained with the SD-8447 spray alone. A water extract of silks increased mortality approximately 20%, while a water extract of leaves gave no apparent effect. No increased mortality was obtained when fall armyworm was used as the test insect.

At Tifton research has continued on sex pheromones of fall armyworm, Spodoptera frugiperda, corn earworm, Heliothis zea, and beet armyworm, S. exigua. In all three species the pheromone was found in the last abdominal segment. The pheromone of female fall armyworm moths was isolated in pure form and identified as cis-9-tetradecen-1-ol acetate. Its chemical structure was verified by synthesis. The pheromone is now being evaluated in the field for attractancy. This material did not excite males of corn earworm nor beet armyworm when tested in the laboratory.

A laboratory procedure has been worked out at Tifton for the collection and isolation of sex pheromone of corn earworm. Active fractions from both laboratory-reared female moths as well as from moths caught in light traps elicited copulatory attempts on males.

The crude extracts from each of the above-mentioned three species of insects are specific in eliciting a sexual behavior in the respective male moth. No overlap of activity has been obtained in laboratory assay. However, crude extracts of corn earworm and to a slighter extent crude extracts of fall armyworm elicited a reaction in males of cabbage looper, Trichoplusia ni.

In cooperation with Agricultural Engineers at Tifton, Ga., ultrasonics was evaluated for its effectiveness as a repellent to the corn earworm moth. The sound was beamed over a field with a 2-inch diameter LTV transducer which emitted sound waves at a frequency of 31 kc/sec up to a sound intensity of 84.5 db, as measured on a B&K sound meter on the B scale. The transducer was revolved at 324 rpm from 6 p.m. until 6 a.m.

during the tests. Effectiveness of the sound was determined by counting corn earworm eggs, and collecting moths near the transducer in light traps. There was no significant differences between the number of adults or number of eggs near the transducer and in the check area.

2. Small Grain Insects. The larvae of this false wireworm feed on small grain seed in the soil. Preliminary studies at Brookings, S. Dak., have indicated that chemosterilant impregnated wheat serves as a method of introducing these compounds into the larvae. Larvae feeding on 50 ppm tepa treated wheat were killed before pupation. Larvae treated with apholate and metepa at 100 and 500 ppm and with tepa at 100 ppm produced adults that laid few viable eggs. The chemosterilants did not significantly reduce the germination of wheat soaked in the chemicals.

Genetic experiments at Lafayette, Ind., showed that first generation progenies from reciprocal matings between individuals of the Great Plains race and Races A, B, C, and D of the Hessian fly reacted as Great Plains race in that they were able to infest Turkey but unable to infest Vermillion, Monon, and Knox 62, wheat varieties differing in their genes for resistance to one or more races of Hessian fly in the eastern soft wheat region.

These experiments point out the possibility that high density populations of the Great Plains race could be released in local areas in the eastern soft wheat region and theoretically reduce the wild type populations to insignificant numbers 4 to 5 generations after release.

Tests at East Lansing, Mich., showed that apholate was an effective chemosterilant for the cereal leaf beetle. A 0.05% aqueous concentration, applied as a dip, caused 100% sterility of both sexes. When only males were treated a 0.1% solution was needed to effect complete sterility. Longevity of treated males was reduced at the sterilizing dosage, death occurring mostly ten days after treatment. A ratio of treated males to untreated males of about 12:1 would be required to reduce egg viability to zero. Histological sections revealed no damage to the testis of males treated with 0.1% apholate.

An exploratory study of duTer (hydroxytriphenyltin) indicated that it was most effective as a chemosterilant when both sexes were treated. Concentrations of 2.0% and 3.0% caused lethargy, manifested by inactivity and starvation. At lower concentrations, these effects were progressively less pronounced.

Sterility, mating, feeding, and mixing tests were carried out with pre- and post-diapause irradiated cereal leaf beetle males. Irradiation at the pre-diapause stage induced a higher level of sterility than did exposure after the termination of diapause. Exposure levels of 4000 rads and above of beta, gamma, and x-ray significantly reduced feeding of irradiated males. Exposure of adult females at levels of 2000 rads almost entirely eliminated

the production of eggs while levels of 1000 rads resulted in reduced egg production and extremely low hatching percentages. Mixing tests in which males irradiated at 1000 and 2000 rads were mixed with untreated males in varying proportions and mated with untreated females were also carried out. Mixing ratios of nine males irradiated at the 2000 rad level to one untreated male paired with ten untreated females resulted in an over-all reduction in hatching potential of 75 to 84%. The introduction of a competition factor by the inclusion of only a single female caused a further hatching reduction of the magnitude of 5%. Mating tests in which the untreated male and the untreated female were marked indicated that the reduction in mating vigor of males exposed to 2000 rads of beta irradiation is in the region of 7%.

Screening of synthetic materials for use as chemical attractants for the cereal leaf beetle was continued during the past year. None of the candidate materials elicited a response in the cereal leaf beetle.

Wheat stem sawflies, most of which were in the pupal stage of development, were exposed to gamma ray radiation at eight dosage levels ranging from 2,000 to 110,000 rads at Fargo, N. Dak. Reduction in adult emergence was slight at levels below 10,000 rads, treatments of 70,000 and 110,000 rads caused reductions of 59 and 85%, respectively.

Post diapause wheat stem sawfly larvae were exposed to gamma ray radiation at levels ranging from 500 to 3000 rads. Increased dosages reduced the amount and delayed the time of sawfly emergence. These effects were slight at the lowest level (500 rads) but amounted to over 50% reduction in emergence and a three day delay in the 50% emergence point at the highest radiation level (3000 rads). The mean longevity of emerged sawfly adults was reduced from 6.1 days for the non-irradiated larvae to 4.1 days at the 3000 rad treated larvae.

In cooperative studies with Georgia Tech methods are being developed to study the dielectric constant of the exoskeleton of insects to determine if insect spines act as waveguides.

In research conducted under contract with Michigan University electromagnetic attraction studies performed with incoherent radiation sources revealed no gross attraction characteristics with either the corn earworm or fall armyworm.

Studies are being conducted under a cooperative agreement with the Electronic Research Laboratory at the University of California on irradiating insects with narrow band coherent frequencies in the infrared and microwave region to test response of these insects to coherent radiations. Under this same project methods for duplicating infrared and microwave lines from organic chemical scents are being developed.

F. Evaluation of Equipment for Insect Detection and Control

A pneumatic spraying system, developed by the agricultural engineers at Tifton, Ga., was evaluated. Pneumatic nozzles applied 1 and 2 pounds malathion and the 650017 nozzle, 2 and 4 pounds of malathion per acre. Analysis of plants immediately after application indicated residues of 13 and 26 ppm when the F-1 nozzle was used to apply 1 and 2 pounds per acre applications, respectively. Residues of 311 and 825 ppm with 2 and 4 pounds per acre applications, respectively, were obtained with the 650017 nozzle.

In preliminary studies at Tifton, Ga., a modified centrifugal fan in a light trap was compared with gravity light traps. The percent increases in the fan trap catch over the gravity trap were: Granulate cutworm, 19; lesser cornstalk borer, 34; fall armyworm, 56; tobacco budworm, 136; corn earworm, 196; tomato hornworm, 203; tobacco hornworm, 285; and armyworm, 429.

In cooperation with agricultural engineers at Tifton, Ga., a Dynafog aerosol generator was tested for control of the earworm. DDT was fogged directly into the corn each day during the silking period. When the corn ears reached optimum roasting ear stage, they were evaluated for insect damage. About 90% of the ears treated were marketable, which was about equal to DDT applied by conventional spray equipment.

A study designed to develop improved equipment for applying insecticides was continued at Tifton in cooperation with the Agricultural Engineering Division. An experimental duster for research purposes was designed that did not vary in output more than $\pm 2\%$ between applications. A round and rectangular air curtain nozzle was used with the dusting machine with or without an electrostatic charge. The electrostatic charge was set up between the high potential electrode centered about 1-1/2 inches in front of the center nozzle and the outer nozzle. This equipment was compared with a sprayer for corn earworm control. There were no differences in control between any of the dusting nozzles and the conventional sprayer. Ultra-low volume sprayers (1/2 pint to 2 pints per acre) have been modified and tested for corn earworm control. Preliminary data with this equipment show that the flat spray pneumatic nozzle and the flat fan 65° nozzle above the plants were not adequate for insect control. When the nozzles were placed equidistance at ear-height between the rows, insect control was improved. To further improve insect control, an electrostatic charge was placed on the spray particles. To effectively place a charge on the particles, the nozzle was placed inside of a 20 mph air stream. Tests with this equipment showed a significant improvement in insect control. However, later tests indicated that the improved control was due to the air blast and not the electrostatic charge.

G. Varietal Evaluation for Insect Resistance

1. Corn Insects. In continuing tests at Ankeny, Iowa, to locate additional sources of first brood resistance to the European corn borer, 14 of 73 South

Carolina inbred lines of dent corn had a satisfactory degree of resistance. Most of the 32 heterozygous composites, which were derived from crosses obtained from the Rockefeller Foundation were highly susceptible. Two of 14 inbred lines with a fair degree of corn rootworm resistance had a good degree of resistance to the European corn borer.

The value of a recurrent selection technique in selecting for resistance to leaf feeding by the European corn borer has been determined. A group of S_1 lines from five original populations (C_0) and the populations derived from three cycles (C_1 , C_2 , C_3) of selection in each variety were artificially infested in 1965 and 1966. Two cycles of selection were sufficient to shift the frequency of resistance genes to a high level in all varieties. Three cycles of selection produced essentially borer-resistant varieties.

Ninety-eight of 313 S_1 lines from a WF9 synthetic and 198 of 424 S_1 lines from a B14 synthetic had a satisfactory degree of resistance. Approximately 570 individual rows of lines in various stages of inbreeding were rated for leaf feeding resistance. These lines were derived from a variety of sources and represent most of the new lines under development in the corn breeding project.

One phase of the European corn borer resistance program at Wooster, Ohio, is screening inbred lines of dent corn submitted by corn breeders from the Northern States of the North Central Region, for resistant germ plasm. In 1966 the Michigan Experiment Station submitted 623 inbred lines which were screened for corn borer and leaf blight resistance; a considerable number of these lines indicated a good degree of resistance to the European corn borer but most of the lines were susceptible to the northern corn leaf blight fungus. Ten inbreds from Michigan that rated resistant to both the corn borer and blight in 1965 were re-evaluated for corn borer resistance in 1966; eight of these rated resistant and two intermediate in resistance.

Seven of 19 inbreds which had previously been selected for tolerance to maize dwarf mosaic had a good degree of resistance to the European corn borer.

Studies have been continued at Ankeny, Iowa, on the biochemical factors responsible for corn resistance to the European corn borer. It was found that the compounds, 2,4-dihydroxy-1,4-benzoxazin-3-one (DIBOA) and 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA), are produced by germinating corn seeds. DIMBOA concentration in the coleoptile of inbred WF9 (susceptible) is 40X greater than that found in the whorl tissue of the older plant, while DIBOA concentration is 45X greater. In inbred CI.31A (resistant), the DIMBOA concentration of the coleoptile is 5X greater than that found in whorl tissue of older plants, while DIBOA concentration is 7X greater. Radicles of both inbreds contain DIMBOA at a concentration of 5 to 6 mg/g dry tissue and DIBOA at 0.4 to 0.6 mg. DIBOA and DIMBOA are

biosynthesized by the plant upon germination and throughout development of the plant. These compounds apparently play an important physiological role in plant development.

A genetic study of the character high benzoxazinone content in single crosses is underway. Preliminary data show that high benzoxazinone content appears to be a dominant character while low content is recessive. Resistance ratings for the single crosses correlate with benzoxazinone concentration. Concentration in resistant single cross hybrids is ten times greater than that found in susceptible hybrids. Thus, level of corn borer resistance in single cross hybrids and inbreds can be predicted by chemical analysis. Such chemical analysis may be of value as a screening tool for resistance in corn breeding programs devoted to the development of superior hybrids with more satisfactory corn borer resistance.

In Mississippi southwestern corn borer resistance studies of 34 dent corn commercial hybrids, one experimental hybrid and 29 single crosses showed no significant differences among hybrids based on percentage of infested and/or girdled plants. Greenhouse studies were conducted to determine the susceptibility or resistance of eight inbreds to the southwestern corn borer. Four of the inbreds were southern (Mp414, SC 149, F₆, F₄₄). The other four were northern inbreds (B 49, CI31A, B 37, WF9). B 49 and CI31A are highly resistant to the European corn borer. B 37 and WF9 are highly susceptible to European corn borer attack. The results showed all eight inbreds to be susceptible to the southwestern corn borer.

Of 62 hybrids evaluated for rice weevil resistance at State College, Miss., several showed good resistance. Kernel infestation ranged from 1.0% in Pennington 7-C-11-A to 46.5% for PAGS x 59 and Funk G 4703.

Twenty-five corn hybrids were rated for corn earworm damage at Temple, Tex. All were badly damaged. Texas 30 and Texas experimental hybrid 6689 had the least amount of damage with .63 inch penetration of the ears and 90 and 93% of the ears infested.

Twenty-seven commercial hybrids and 9 Texas experimental hybrids were rated at College Station for earworm damage. Texas 36A with an average earworm penetration of .23 inch with 73% of the ears infested was the most resistant. Ten experimental white hybrids out of 15 at Baton Rouge, La., showed high resistance to the corn earworm. The best hybrid was La. experimental 6119 with an average penetration of .17 inch and only 57% of the ears infested.

Corn lines selected for varying chemical content were evaluated for corn earworm and fall armyworm resistance at Tifton, Ga. In a field test, corn kernels with low amylose content seemed to have more earworm damage than kernels with high amylose content. In addition, kernels with high lipid or high carotene content had more damage than kernels with low lipid

or low carotene. A second part of this test involved a fat analysis of larvae reared on these same corn lines. Indications are that larvae reared on the low amylose corn lines contain the least fat, while larvae reared on the high protein lines contain the most fat. Larvae from the high lipid line contained more fat than larvae from the low lipid line. The opposite was true for the high and low carotene lines.

Corn inbreds 81-1 and 471-U6 make up the desirable and earworm resistant sweet corn "Walter's White" and are difficult to maintain and use in a crossing program. Several hybrids made from inbreds produced in a backcrossing program with 81-1 and 471-U6 have shown considerable promise in retaining quality and earworm resistance. Improvement has been made in vigor and shortening the silking date of the 81-1 backcrosses, at least as inbreds. Improvement has also been made in 471-U6 backcrosses as to ease of handling in a hand-pollination program.

A study of the relationship of corn earworm damage with ear husk tightness and larval development indicated highly significant differences among corn lines for husk tightness, depth of larval penetration, and larval weights (seven days after infesting). A highly significant negative correlation coefficient ($r = -.513^{**}$) indicated a relationship between husk tightness and depth of larval penetration. Husk tightness and larval weights from field ears had a highly significant negative correlation ($r = -.582$). Depth of larval penetration in the field ears at seven days and larval weights from these ears showed a highly significant correlation ($r = .541^{**}$).

At Tifton ten corn lines selected for varying chemical content were laboratory screened for rice weevil resistance. Highly significant differences existed among lines in the number and weight of the weevil progenies reared per line. The number of progeny and their respective weights were not significantly correlated. Lines PI 217413 (hard flint type kernels) and Wx 38-11 (low amylose) produced significantly fewer weevil progeny than did lines SC 249a (high lipid), CI 21 (low carotene), and Mp488 (high carotene). Line T-115 ae (high amylose) produced significantly more weevil progeny than did line Wx 38-11 (low amylose). Line SC 246c (high protein) produced heavier progeny than line SC 256 (low protein). A super sweet line produced the lightest progeny. Fat analysis of progenies reared on these lines ranged from an average of 201.8 μg per insect on line Wx 38-11 (low amylose) to 261.2 μg per insect on line Mp488 (high carotene).

Seventy-five corn lines containing germ plasm from Central and South American lines as well as germ plasm from a number of southern dent inbreds were laboratory screened at Tifton, Ga., for resistance to the rice weevil. Statistical analysis indicated that a highly significant difference existed among certain entries for the number of rice weevil progeny produced on these lines. The entry Eto x Manfredi R(2)1-1 appeared to be the most resistant to rice weevil within the conditions of this evaluation

while corn line entry P.R. 9D x CBC(2)1-1 appeared to be the most susceptible. The more resistant entries tended to have a relatively large number of kernels that were not damaged while the more susceptible entries tended to have few, if any, undamaged kernels at the end of 56 days after initial infestation.

Evaluation of corn lines for rootworm resistance was continued at Brookings, S. Dak. Nineteen S₂ and 13 S₁ corn lines survived a heavy rootworm infestation in the field in 1966. These lines have survived a number of tests over the past years. If their 1967 performance is equal to their previous ratings, some of the lines may be considered for formal release.

The 1966 performance of F₁ and S₁ lines provided added support that HD2187, SD10, B14, CI21E, and Mo22 are usually involved in the superior crosses. SD10 X B14 showed considerable promise in a number of tests.

Further evidence of progress in identifying and breeding for resistance to corn rootworm is shown by the poor performance of untested lines as compared with lines that have been retained from earlier tests. Over twice as many of the retest lines had a satisfactory rating as compared with the new material tested. Of the 90 plant introductions, only one was resistant.

In studies conducted under P.L. 480 project in India, techniques for measuring the resistance of corn to the borer, Chilo zonellus, have been developed, and some varieties were found with a moderate degree of resistance to this borer.

In research conducted at Ames, Iowa, under a research grant, two previously unreported cyclic amides related to the cyclic hydroxamic acids have been isolated from the corn line 31a. A method for labelling DIMBOA and DIBOA with carbon 14 was developed and a method for estimating the amount of DIMBOA in corn was found.

Research is being conducted under a cooperative agreement with the Missouri Experiment Station on the nature of corn earworm resistance in corn. The length of silk channel has been determined as an important factor contributing to resistance of inbred lines.

2. Small Grain and Sorghum Insects. At Bozeman, Mont., spring wheat varieties were screened to find wheats resistant to sawfly under all environmental conditions. One variety P.I. 94585 and selections from this variety have a stem solidness character which is more stable under varying environmental conditions than the resistant variety, Rescue.

At Fargo, N. Dak., it was determined that the main effects of wheat variety, time of planting, and time of sawfly oviposition on sawfly infestation and damage are separable. The number of elongated internodes

is a function of wheat variety and planting date. The number of elongated internodes influenced oviposition rates and sawfly infestation or damage. Associations between stem elongation and other plant characters were determined.

At Minot, N. Dak., no inter-row preferences for oviposition among rows of wheat bordered or not bordered by a wheat stem sawfly susceptible variety of wheat could be determined. Differences in rates of oviposition were the result of differences among varieties in the number of elongated internodes and other factors at the time of sawfly flight and oviposition. Oviposition and damage were not influenced by the sequence in which the varieties were planted or by the presence or absence of an adjacent row of a sawfly susceptible wheat. This information is important in both the biological and statistical senses because it demonstrates that the sequence of varieties in single row plots of multi-variety plantings does not influence sawfly oviposition or damage.

At Brookings, S. Dak., a test, screening 66 varieties of spring and durum wheat for resistance to the wheat stem maggot, indicated that the hard red spring wheats: Pembina (C.I. 13332), Kenya 184 X Wisc. 250 4 (C.I. 13588) and Crim (C.I. 13465) and the durum wheats: North Dakota Sel. 58-274 (no C.I. or P.I. number), RL 3394 (C.I. 13583), and Yuma (C.I. 13245) may possess some resistance to the wheat stem maggot.

At Stillwater, Okla., it was determined that greenbug-resistant Will barley maintained resistance to greenbugs from various sources and to all strains both under laboratory and field conditions. The factor responsible for resistance in barley, apparently, is different from that in wheats because wheats which were formerly resistant are now susceptible to the several greenbug strains.

At Stillwater 14 greenbug-resistant oat selections were retested, 13 were susceptible to the new greenhouse strain. One of the entries, P.I. 186270, Avena Selecta M.C. 41374 I.F., from Argentina, which had been reported in 1961 as being one of the most resistant oats to the "normal" greenbug strain, was also resistant to the new biotype. Crosses involving this oat with resistance to both greenbug biotypes are being made.

In studies conducted at Stillwater under cooperative research agreement, it was found that a greenbug susceptible barley variety Rogers contained 1-1/2 times as much ninhydrin as resistant variety Will. In this project progress has been made in developing a bioassay method of evaluating plant extracts and in obtaining salivary fluids and honey dew from grain aphids for chemical analyses.

The 1966 Indiana Hessian fly survey showed that Race B field populations of Hessian fly, capable of infesting Dual, Monon, Redcoat, Reed, and Riley wheats having the H₃ resistance, continue to be a threat to these varieties although the average infestation for the State was slightly lower

than last year. Samples from 317 certified wheat fields showed 69% of them to be infested as compared to 84% last year. Knox 62, having the H_6 gene for resistance, continues to remain comparatively uninfested, with an average infestation for the state being less than 1%, whereas varieties carrying the H_3 gene averaged 7.6%. Benhur, released this year, also has the H_6 gene for resistance and is also expected to suppress the fly populations in areas where it is planted.

In lower Michigan, Hessian fly infestations during the crop year 1965-66 decreased considerably from the previous year. Samples from 175 certified wheat fields showed 38% of the fields to be infested with Hessian fly. The average infestation for wheats having no Hessian fly resistance was 2.3%, and 2.2% for wheats having the W38 resistance. The racial composition of two populations showed Race A to be the predominant race, but Races B and D, which are capable of infesting W38 and PI 94587 resistant varieties, were present in small numbers.

Wheat varieties resistant to Hessian fly are widely used in the critical area of North Central and Northeastern Kansas but serious reductions in their use has occurred in some counties. The resistant varieties, Gage, Warrior, and Parker which are now available should result in increased acreage of resistant varieties.

Wheat breeding material from four State Experiment Stations in the eastern soft wheat region and three State Experiment Stations in the hard red wheat region were evaluated for Hessian fly resistance at Lafayette, Ind., and Manhattan, Kans. Approximately 11,500 lines, hybrids, varieties, or selections were included in these tests. Wheat reactions to Hessian fly were recorded and forwarded to wheat breeders involved, and in some instances resistant plants were air mailed to wheat breeders for further selection or crossing.

Approximately five and one half thousand head selections, hybrids, and lines from the Purdue regular fly nursery, preliminary yeild nursery, advanced yield nursery, fly stem rust nursery, and Septoria nursery were evaluated for resistance to Races B and D. All wheats have one or more of the H_3 , H_5 , H_6 , or Marquillo genes for resistance in their parentage. Many of the F_2 and backcross lines containing the H_5 gene in combination with one or more of the H_3 or H_6 genes were saved, vernalized to break the winter habit, and utilized in the crossing program in the greenhouse. Two Hessian fly resistant soft red winter wheats were released by the Indiana Experiment Station in cooperation with the Entomology and Crops Research Divisions: Riley 67, an improved wheat having the H_3 gene for resistance, and Benhur, having the H_6 gene for resistance to Races A and B.

At Lafayette, Ind., experimental populations of Hessian fly are being studied to determine differences in natural fitness in Hessian fly races when reared on a non-resistant variety offering no selection and to determine the effectiveness of selection by resistant varieties in changing the

gene frequency of populations. Intensifying selection by gradually increasing W38 resistant plants to 100% of the plant population has changed the initial frequency of .95 Race A and .05 Race B in the first generation to .1 Race A and .9 Race B after eight generations. No significant change has occurred in the initial frequency of .95 Race A and .05 Race B of control populations reared on a non-resistant wheat.

A new race of Hessian fly, Race E, has been isolated from a population of Hessian fly collected in Georgia. This race differs from all known races in that it is capable of infesting wheats susceptible to Race B but is unable to infest wheats susceptible to Race A.

The first emergence of Hessian fly from stubble collected in western Kansas is predominantly the Great Plains race of fly. If this first greenhouse population is carried through on a continuous development basis, it quickly shifts away from the Great Plains race and becomes predominantly Race A or B. If, however, this first greenhouse population is put in the refrigerator from three to six months before it is used, the percent of Great Plains race of fly that will emerge is greater than when reared on a continuous development basis, but it is still not as high as the original material.

Work was continued in Michigan and Indiana on the evaluation of wheat, oats, and barley for resistance to the cereal leaf beetle. Successful crosses have been made between cereal leaf beetle resistant wheat varieties and adapted hard red winter wheats, hard red spring wheats, soft winter wheats, and durums. In the 1967 field tests 29 F₄ progenies from crosses with the spring variety Crim and 62 F₄ progenies from crosses with the spring wheat Chris had only trace amounts of cereal leaf beetle damage under a heavy infestation. In this same test 211 F₄ winter lines showed a high degree of resistance.

At Purdue breeders have used pubescent spring and winter wheats Agropyron sp. and Triticum persicum, as resistant parents crossed with Hessian fly resistant adapted wheats. Michigan workers have introduced resistance to the beetle into 23 crosses involving commercial varieties or advanced lines.

There are no highly resistant oats to the cereal leaf beetle, but two lines C.I. 7495 and C.I. 4991 have shown some resistance.

There are three or four lines of barley that have a good degree of resistance to the cereal leaf beetle. These include C.I. 6469, C.I. 6671, and C.I. 12225.

Greenhouse techniques have been developed at East Lansing, Mich., to evaluate cereal leaf beetle resistance in small grains. These methods include rate of larval growth, adult feeding preference and adult oviposition preference. By using these methods, lines of winter and spring wheats were isolated which are highly resistant to the cereal leaf beetle.

These lines included C.I. 8519, 8529, 8520, 9321, 9320, 9294, P.I. 280446, 238405, and 182750. Spring barleys (C.I. 6671 and 12225) and oats (C.I. 7495 and 4991) have also been found to possess some resistance to the beetle.

Resistance to the cereal leaf beetle in wheats is related to the amount and type of leaf pubescence. Pubescence has a three-fold effect on the beetle, acting as a deterrent to oviposition, promoting desiccation of eggs, and inhibiting first instar larval feeding.

Barley and oat resistance is related to non-preference for oviposition.

At Tifton, Ga., 30 sorghum lines were evaluated in greenhouse tests for resistance to fall armyworm larval feeding. Results indicated highly significant differences among lines rated for leaf feeding as well as the number of larvae found per plant. There also was a significant positive correlation ($r=0.38$) between damage ratings and the number of larvae recovered per plant. A low correlation ($r=0.12$) between damage ratings and larval weights resulted.

Grain sorghum leaves (30 days after planting date) and heads (10 days after 50% bloom) were harvested from each of 10 lines, lyophilized, and incorporated into an agar-chromic oxide diet. Each diet was bioassayed for percent utilization by fall armyworm larvae. Results indicated a range in utilization from 13.2 (low) on line CI 623, a Feterita, to a high of 36.8 on line SPI 34911, a Hegari. Both of these entries are dual grain forage sorghums. The only forage sorghum in the test, FC 13614, had low utilization while the grain sorghum FC 8913 had comparatively high utilization by fall armyworm larvae. Percent utilization of leaves showed a smaller range (27.9-39.7) among entries than was shown by the heads. Again, the forage type had low utilization.

Grain from 84 sorghum lines was evaluated for rice weevil resistance at Tifton, Ga. The number of weevil progeny produced on each line after being infested with parent weevils was recorded and a fat analysis was determined for weevils reared on the various lines. Results indicate a range of 0.8 progeny per female on line CI 580, a broom corn, to 32.0 progeny per female on line TS 23240, a Kaoliang. In general, the broom corn and sorgo types produced the fewest progenies while the Kaoliang and kafir types produced the most. Differences in number of progeny per female and fat content of progeny reared on the various lines were significant at the 1% level. Range of fat content per insect varied from 4.15% on ODC (midge resistant lines from South Africa) to 11.88% on FC 9111 (orange).

Two-hundred-and-nine sorghum lines were evaluated in the field for resistance to the sorghum midge. Average midge emergence per head ranged from a low of one per head on 15 lines to a high of 20, or more, per head on 52 lines. Lines of particular interest from a resistance standpoint are: CI 623, SPI 34911, SA 1595, Wiley, CI 27, WD 623 x 807-18, SA 310, FC 8728, FC 16205, CI 918, HC 617, FC 8986, Reliance, and ODC 19.

At Stillwater, Okla., 144 sorghum varieties were manually infested in the early whorl stage of plant development with corn earworm, fall armyworm and southwestern corn borer eggs in the "black-head" stage to test them for resistance to these insects. Nineteen showed resistance to the corn earworm and 61 to the fall armyworm. Southwestern corn borer resistance was shown by 12 of 75 entries.

In Zaria, Nigeria, one sorghum line was found that showed tolerance to the sorghum midge.

H. Insect Vectors of Diseases

1. Corn Insects. A nonpersistent virus was isolated from naturally infected field corn at Brookings, S. Dak., during the 1966 growing season. The virus reacts like brome mosaic virus (BMV) in certain aspects of its symptomology and host range. However, it has not proven to be infectious in garden beets, cucumber, tobacco, or snap beans, all of which are reported as hosts of BMV. Preliminary investigations have shown that several monocotyledonous plants, i.e., barley, Hordeum vulgare; wheat, Triticum aestivum; corn, Zea mays; yellow bristlegrass, Setaria lutescens; and barnyard grass, Echinochloa crusgalli, develop systemic infections of the virus when they are mechanically inoculated with whole freshly extracted sap from corn. The symptom syndrome produced by infections of the virus in Golden Bantam sweetcorn is progressive from lenticular local lesions on the inoculated leaves to a systemic infection resulting in wilting and tip necrosis of the whorl leaves, to collapse and death of the seedlings within 10-14 days after inoculation.

Vector tests with the greenbug, corn leaf aphid, apple grain aphid, English grain aphid, and the green peach aphid have been negative.

In Mississippi many inbreds, single crosses and double crosses including widely grown commercial hybrids were evaluated for corn stunt virus infection. Resistance or susceptibility was apparent in all corns rated. Fortunately, there is a high degree of resistance in many of the commercially established hybrids.

Transmission efficiency of the apple grain and English grain aphid was studied at Brookings, S. Dak., after aphids fed through a Parafilm membrane on suspensions of barley yellow dwarf (BYDV). Transmission of BYDV after feeding on virus-containing sucrose or complex diet solutions was generally low and variable. Rhopalosiphum padi was more efficient than Macrosiphum avenae. Increases in acquisition feeding periods did not result in a corresponding increase in virus transmission or numbers of stylet sheaths formed in solutions. Greatest numbers of stylet sheaths were counted in diet preparations.

At Brookings, S. Dak., field plots of 35 hard red spring wheats infected 100% with BYDV showed yield losses above 50%. Highly significant differences

between healthy and diseased and between varieties were reflected in yield, height, and maturity.

Research conducted under cooperative agreement at Wooster, Ohio, has shown that the wheat curl mite, Aceria tulipae, secretes a phytotoxin that causes kernel red streak of corn. Some lines are more sensitive to the toxin than others.

Studies on the transmission of corn viruses by aphids and leafhoppers is being conducted under a research grant by the Missouri Experiment Station. Mass rearing techniques have been developed to rear several species of leafhopper for large-scale transmission tests. One insecticide, Niagara NIA-10242, has shown promise in controlling the vectors.

Research has continued at State College, Miss., under a research grant to determine the role of leafhoppers in the transmission of corn stunt. Dalbulus maidis, one of the vectors migrates into the United States each year from Mexico. Graminella nigrifrons, another vector is the most abundant species in corn. Gammagrass has been proven a host plant for both of these vectors. At least 35 species of grasses are host of the corn stunt virus.

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RICE INSECTS
Entomology Research Division, ARS

Problem. Several species of insects including leafhoppers, the rice stink bug, rice water weevil, grape colaspis, stalk borers, and the sugarcane beetle damage rice in the rice-growing areas of the United States. Progress has been made toward the solution of some of the insect problems encountered in the production of rice but more effective, more economical, and safer insect control measures are needed. The appearance of resistance to certain insecticides in some rice insects stresses the need for basic information to overcome this problem. Additional emphasis should be given to new approaches to control rice insects and to evaluate rice varieties for resistance to major rice insects.

USDA AND COOPERATIVE PROGRAM

The Department's program on rice insects involves entomologists, agronomists, and plant breeders, and plant pathologists engaged in both basic studies and in the application of known principles to the solution of growers' problems. The research is being conducted at Baton Rouge, La., in cooperation with the Louisiana Experiment Station. Basic research on the control of damage by larvae of the rice water weevil, Lissorhoptrus oryzophilus, by increasing plant tolerance, is being conducted under a grant with the University of Arkansas, Fayetteville, Ark. Under PL 480, A7-ENT-5, India, a survey is being made of the natural enemies of pests of paddy.

The Federal scientific effort devoted to research in this area totals 1.2 scientist man-years. Of this number 0.3 is devoted to basic biology of the leafhoppers, rice stink bug, and rice water weevil; 0.3 to insecticidal control of rice stink bug and rice water weevil; 0.4 to varietal evaluation of rice for resistance to stink bug, rice water weevil, and vectors of rice diseases; and 0.2 to program leadership. In addition Federal support for research in this area provides for 0.4 man-year in a research grant to the University of Arkansas for varietal evaluation of rice for resistance to the rice water weevil.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 3.3 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

At Baton Rouge, La., investigations have been continued on the biology of the rice water weevil. Photoperiod, water temperature, and light intensity were found to be factors involved in the reproduction of this insect. The

optimum condition for maximum reproduction as found in the greenhouse study, was a 14-hour day-length, 85° F water temperature and at least 3300 foot candles of light. Adult weevils removed from bunch grass during the winter copulated within minutes after emerging and oviposited within 6 days. Egg hatch averaged 4-1/2 days, larva matured within 21 days and adult emergence occurred within 26 days.

A newly initiated study of the seasonal history and flight activity of the rice water weevil and green rice leafhopper, Draeculacephala portola, using light traps, yielded data showing three population peaks for the rice water weevil during the spring and summer of 1966. These data support previous observation reports of 3 summer generations annually. These data also indicated that night temperature influences the flight activity of this insect and activity ceases with a temperature decline to 63° F or below. A laboratory study supported these findings where the adult weevils became almost completely immobile at 60° F. This information has provided a means for retaining large numbers of the adults for winter studies in the greenhouse and laboratory. From these data it appears that four or more summer generations of the green rice leafhopper occur with the third and fourth generations overlapping.

A study consisting of weekly sampling of bunch grasses from November 10, 1966, to May 15, 1967, for adult rice water weevils revealed low mortality occurs during overwintering. The sex ratio of the overwintering population until about April was almost 1:1 but after April 1, the sex ratio shifted to about two females for each male in overwintering quarters.

Overwintering counts taken throughout the winter on stem borers, Chilo plejadellus and Diatraea saccharalis revealed low mortality occurred in rice stubble.

B. Insecticidal and Cultural Control

Low volume concentrate malathion at the rates of 5 and 9 oz was tested against the rice stink bug, Oebalus pugnax. Neither of the LVC rates were effective as the 0.5 pound emulsifiable concentrate spray. At the 9 oz rate the LVC appeared to be effective against nymphs but not against adults. The 9 oz rate provided effective control of grasshoppers and green rice leafhoppers.

Eleven candidate insecticides alone and five in combination with aldrin were compared with aldrin seed treatment in 1966, for rice water weevil control, but none gave adequate protection. Some interaction occurred between propanil, a herbicide commonly used in grass control on rice, and many of the seed treatments with phosphate or carbamate insecticides. This interaction was characterized by leaf burn on seedling rice and subsequent yield loss where 25% or higher leaf burn occurred.

Six candidate insecticides were compared with aldrin as a granular application, post flood. Only Niagara NIA-10242, at the 1/4 and 1/2 pound toxicant per acre rate, and Bay 25141 at the 1 pound or higher gave satisfactory control.

C. Varietal Evaluation for Insect Resistance

Three nurseries, the Uniform Yield Nursery, Arkansas Disease Nursery, and International Blast Nursery, containing a total of 490 varieties or selections were evaluated for host plant resistance to the rice water weevil and the two stem borers, Chilo and Diatraea. No significant differences were found in resistance of these varieties/selections to any of the insect pests.

Research was conducted by the University of Arkansas under research grant to determine if the feeding site of the rice water weevil adult was associated with plant nutrients. Chemical analyses of leaves from each leaf position of rice plants ranging in age from 12 to 52 days were compared with adult feeding activity on the respective leaves. The preferred feeding site of the adult could not consistently be associated with changes in the level of the 12 plant constituents analyzed from the various leaves.

D. Insect Vectors of Diseases

At Baton Rouge, La., virus acquisition was determined for 9 to 10 day old adults of Sogatia orizicola, which were the progeny of reciprocal crosses of hoja blanca virus (HBV) transmitters to non-transmitters. During nymphal development these adults were exposed at various lengths of time to diseased rice leaf tissue to allow them to feed. Planthoppers exposed to HBV diseased plants for short periods did not show any appreciable difference from individuals that had not been exposed to the virus. It appeared that the virus is primarily acquired transovarially from the female parent.

Individuals that acquired HBV transovarially had a decreased adult longevity; however, the total life span of insects that were progeny of HBV transmitting females was not significantly different from the progeny of non-transmitters.

Adults, 9-10 days old, were mated in all possible combinations of HBV transmitters to non-transmitters. The number of eggs resulting from these different matings were not significantly different.

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FORAGE AND RANGE INSECTS
Entomology Research Division, ARS

Problem. Numerous insect pests that attack forage and range plants in various parts of the United States lower seed production, reduce the quantity and quality of forage crops, and decrease the abundance of range plants for the grazing of livestock. Certain insects are involved in the transmission of forage-crop diseases. Among the more important insect pests are grasshoppers, lygus and other plant bugs, stink bugs, seed chalcids, the alfalfa weevil, root borers, spittlebugs, leafhoppers, and a variety of aphids including the spotted alfalfa aphid and the pea aphid. A variety of insecticides is used to control these insects but they are often costly and may create residue hazards in meat and milk as well as adversely affect wildlife. There is great need for more efficient insecticides that can be applied on forage crops and range vegetation without leaving residues harmful to man or animals or that might harm bees and other pollinating insects. Increased attention should be given to the development of non-chemical control methods. The search for insect parasites, predators, and pathogens and ways to employ them effectively should be emphasized in research. The development of crop varieties which resist attack by insects offers economical and safe insect-control procedures. Forage crops should be evaluated for resistance to major insect pests and resistant germ plasm should be made available for use by the plant breeders in crop-improvement programs. Basic studies are also needed on the feeding habits of grasshoppers under different environments that affect the abundance of these insect pests. New approaches to control of forage and range insects, such as sterilization techniques and sex attractants, should be investigated.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research on forage and range insects. Studies on varieties of alfalfa resistant to insects are cooperative with State and Federal agronomists and plant breeders, those on plant disease transmission by insects with plant pathologists, and research on insecticide residues with chemists. Grasshopper research at Bozeman, Mont., and Mesa, Ariz., is cooperative with the respective State Experiment Stations. White-fringed beetle research is conducted at Gulfport, Miss. Investigations on alfalfa insects are being conducted at Mesa, and Tucson, Ariz., Lincoln, Nebr., and Beltsville, Md., in cooperation with the Experiment Stations in these States. Research on clover and turf grass insects at Corvallis, Oreg., is conducted in cooperation with the Oregon Experiment Station. Work on grass insects, plant disease transmission by insects, and insecticide residues at Tifton, Ga., is cooperative with the Georgia Experiment Station. Research on insecticide residues is conducted at Beltsville, Md., Tifton, Ga., and Yakima, Wash., in cooperation with the Washington Experiment Station. Studies on varietal resistance, insect vectors of

plant diseases, and grass insects at University Park, Pa., is cooperative with Experiment Stations in 12 Northeastern States. Certain phases of the research on forage and range insects are contributing to regional projects: W-37 (Natural factors Responsible for Grasshopper Population Changes), NC-52 (Factors Influencing the Distribution and Abundance of Grasshoppers), and S-55 (Alfalfa Insects).

Three contracts, 11 grants, and 2 cooperative agreements with State Universities and Experiment Stations will provide additional research on insect biology, physiology, and nutrition, biological control, attractants, and varietal resistance.

The Federal scientific effort devoted to research in this area totals 21.5 scientist man-years. Of this number 3.5 man-years are devoted to basic biology, physiology, and nutrition, 5.0 to insecticidal and cultural control, 2.2 to insecticide residue determinations, 4.0 to biological control, 0.6 to insect sterility, attractants, and other new approaches to control, 0.5 to evaluation of equipment for insect detection and control, 4.1 to varietal evaluation for insect resistance, 0.2 to insect vectors of diseases, and 1.4 to program leadership.

In addition Federal support of research in this area under contracts and grants provides a total of 4.3 scientist man-years. Of this total 1.0 is devoted to basic biology, physiology, and nutrition, 1.0 to biological control, 0.4 to insect attractants and other new methods of control, and 1.9 to varietal evaluation of insect resistance.

Two P.L. 480 projects are underway: E21-ENT-9, "Insect Vectors of Virus Diseases of Various Forage Legumes" with the Research Institute of Plant Protection, Poznan, Poland, completed January 1967, and A10-ENT-6, "Acoustic Responses of the Desert Locust (Schistocerca gregaria Forsk.), Moroccan Locust (Diciostarus maroccanus Thbg.), and Acrotylus insubricus Scop. (Orthoptera, Acrididae)" with the Hebrew University of Jerusalem Jerusalem, Israel.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 46.6 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology and Nutrition

1. Grasshoppers. Ecological studies on grasshoppers in relation to plant damage were continued in 1967 on rangelands in central and southeastern Arizona. Hatching of spring-group grasshoppers began earlier than normal, and populations were higher than in 1966, due chiefly to the warm and dry fall weather in 1966 that extended the egg laying period of female adults.

Densities declined by late June owing to both a dispersal of late instar nymphs and adults and dry food plant conditions.

Studies on plant damage by grasshoppers on the San Carlos Reservation were continued on two 20-acre range plots and a 3200-acre fenced enclosure. Each 20-acre plot is subdivided into two fenced and two unfenced plots. Since 1956 insecticide applications have been made with ground equipment as needed to give effective season-long control of grasshoppers on one-half of each plot. The average square yard grasshopper numbers for the period April-July 1966 in untreated fenced and grazed plots were 1.9 and 2.2, respectively. Loss of weedy and grass herbage in spring was negligible due to an abundance of plants. By July 14 percentages of grass eaten by one 'hopper per square yard in the fenced plot with a grass cover of 21.1% were 7.6% on blue grama, 10.9 on curly mesquite, and 11.1 on squirrel-tail. In local areas having low populations of grasshoppers, scattered squirrel-tail plants were completely defoliated and a lack of blade growth in spring 1967 indicated that these plants were dead. In 1967 damage to grass blades by low numbers of grasshoppers is much greater than in 1966 due to the short growth of grass and a lack of weedy grasshopper food plants.

Preliminary data at Bozeman, Mont., show that the grasshopper, Melanoplus bruneri, often found in high altitudes mountain meadows, appears to pass through two consecutive winters in the egg stage. Eggs were collected from two locations during the summer of 1966 and various handling methods were attempted to induce hatching, but only partial success was achieved.

At Manhattan, Kans., under a grant to Kansas State to study the food plants of grasshoppers on rangeland versus cultivated pastures, it was shown that grasshoppers appeared earlier and developed more rapidly in cultivated pastures than on rangeland.

Research in Israel under P.L. 480 Project A10-ENT-6 showed that when masticating sounds of the desert locust were recorded and played back to nymphs a response to food occurred. Two types of sound were produced by Moroccan locust, one with a definite rhythm produced only by males and one with no discernable rhythm produced by both sexes. Stridulatory sounds were produced only during daylight hours.

2. Alfalfa Insects. Recent laboratory studies at Lincoln, Nebr., have demonstrated conclusively that two strains of the spotted alfalfa aphid exist which differ in their ability to produce sexual forms when subjected to the proper environmental conditions. By periodically subjecting field collected aphids to the conditions which cause formation of sexuales, it was demonstrated that from May through July, 1966, 100% of the population sampled near Lincoln was of the sexual or holocyclic strain. Aphids (heterocyclic strain) incapable of producing sexuales were not collected until late August and were probably migrants from more southern areas. The two strains appeared to occur more or less in equal numbers in the field population from late September until aphid activity ceased.

At Mesa, Ariz., eight environmental chambers were programmed using four temperature regimes (40, 55, 70, 85° F) and two day-length cycles (8 and 16 hours). Adult alfalfa seed chalcids were caged on excised racemes and allowed to oviposit for periods up to 48 hours prior to exposure in chambers. Results showed that 8 hours of light per day at all temperature regimes did not produce an adequate infestation to detect diapausing larvae. At the 16-hour day-length cycle a high percentage of diapausing larvae were produced at all temperature regimes except 40°. Nearly one-third of the infested seeds had diapausing larvae but there were no differences in percent of larvae in diapause among different temperatures.

In studies at Mesa, Ariz., field populations of the alfalfa seed chalcid entered larval diapause on August 31 when the photoperiod was 12 hours and 54 minutes. At that time only one percent of the population had entered diapause. Following that date diapausing larvae increased at a rate of 10% a week until October 26 when 90% of the population had entered diapause. Termination of field diapause occurred during late May when less than 5% of the larvae were in diapause. The photoperiod was slightly less than 14 hours, although temperature is believed to be the primary factor terminating diapause.

In greenhouse tests at Mesa, Ariz., over 75% of the nymphal and adult populations of lygus bugs died after confinement for three weeks on eight different growth stages of Moapa alfalfa plants. Lygus bugs failed to develop satisfactorily on plants representing growth stages from seedling to bud.

In laboratory tests at Tucson, Ariz., several thousand lygus bugs were successfully reared in captivity on fresh beans treated with solutions of 10% sucrose, 10% honey, or tap water. Although adult mortality was higher on beans treated with solutions of 10% honey, no significant difference in nymphal mortality was observed among beans treated with different sugars or tap water.

At Mesa, Ariz., damage to alfalfa by the Egyptian alfalfa weevil was higher in 1967 than in previous years. Populations of larvae per sweep averaged 4.7 in February, 174.0 in March, and zero in mid-April.

Field plantings of six legumes at Beltsville, Md., to determine their relative suitability as hosts for the alfalfa weevil confirmed previous laboratory studies. Alfalfa was completely defoliated in the spring of 1967; the other legumes sustained minor damage corresponding to larval populations. The number of larvae per square foot for alfalfa was 303, white sweet clover 95, hairyvetch 34, alsike clover 7, ladino clover 4, and red clover 3. A survey of farmers' fields in Maryland supported the above. Ladino clover and hairyvetch were infested by larvae but damage was negligible. Larvae collected from red clover heads and reared for positive identification were 65% lesser clover leaf weevil, Hypera nigritostris, 29% clover head weevil, H. meles, and only 7% alfalfa weevil, H. postica.

In Maryland and New Jersey in 1967, both adult and larval populations of the alfalfa weevil were higher than for the previous year. Larval populations developed early in central Maryland and southern New Jersey, and remained high for nearly a two-month period which was much longer than normal. Populations were relatively light in northern New Jersey. Significant correlations were obtained between numbers of overwintering adults and peak larval populations among individual fields in both States. It seems likely that rough predictions of damage potential can be made on the basis of winter surveys for adults. The decline of adults from November to March has been roughly the same each year varying from 58.5% to 66.7%.

At Beltsville, Md., the normal summer diapause of adult alfalfa weevils was effectively terminated by topical application of the synthetic hormone, 10,11-epoxyfarnesenic acid methyl ester. A dosage of 100 μ g of the epoxide per weevil invariably resulted in increased activity and feeding within three days and oviposition began in about seven days. Feeding, mating, and oviposition then continued at normal dates. The same response was elicited from weevils in diapause regardless of their age. On several occasions, a parasite, Microctonus sp., emerged from hosts 14 days after treatment. Practical possible uses of the hormone include: (1) continuous rearing in the laboratory of insects that normally diapause in the adult stage, (2) immediate use in the laboratory of adults collected from the field in the diapausing state, (3) control of insects in the field by disrupting their normal life cycle.

A pronounced crowding effect on alfalfa weevil oviposition was demonstrated at Beltsville, Md. Two weevils per pint or gallon container produced nearly twice the number of eggs per female than 20 or more weevils per jar. Also, changing feeding and oviposition sites daily increased oviposition as compared to changing every two or three days. This suggests the presence of an oviposition deterrent being deposited by females at the time of laying eggs.

In June 1967 a cooperative agreement was initiated with the University of North Carolina to determine the effects of alfalfa saponin fractions on the development and feeding behavior of the alfalfa weevil.

In research on the physiology of lygus bug injury under a grant with the University of California, it was shown that when lygus bugs feed for as short a time as four hours on the floral parts of alfalfa, an abscission layer is formed in one to two days and the bud drops off. Preliminary evidence indicates that the abscission factor is of insect origin.

In a grant to New Mexico State University, techniques for feeding aphids through parafilm under sterile conditions were developed. The mineral requirements, particularly trace elements, of the cotton aphid are under study. Lygus bugs have been maintained for one month on an artificial diet. First and second instar nymphs did not mature but third and fourth instar nymphs matured and deposited viable eggs.

3. Clover Insects. In Nebraska in the fall of 1966, a lepidopterous borer, determined as Walshia miscecolorella, was found tunneling in the crown area and killing the top growth of first year plants of both white and yellow-flowered biennial sweetclover. It is presumed to be the same species, reported under the name W. amorphella, which seriously damaged sweetclover in Texas during the early 1950's. Greenhouse studies indicate that the species passes the winter in the later larval instars. Pupation occurred in loosely spun cocoons in the soil. At greenhouse temperatures moths emerge from the cocoons in about 10 days. Eggs are laid singly on the stems of young seedlings about an inch or two above the soil surface. It is possible that only one generation may occur per year. The only serious damage caused by this insect during the 1966 season occurred in sweetclover breeding nurseries in the vicinity of Lincoln. The insect, however, was detected in 5 southeastern counties but not in several northeastern counties.

4. Grass Insects. To determine the damage caused by a brome grass seed midge, Stenodiplosis bromicola, a pre-harvest head sample was taken from eight southeastern Nebraska brome grass fields. In one sample of Lincoln brome grass, 50.4% of the florets contained diapausing larvae. Approximately 25% of the florets from all samples contained diapausing larvae. The average percent of normal seed in all samples was about 34, indicating that a considerable portion of the 1966 seed crop was lost because of the midge.

At University Park, Pa., three grass-feeding leafhoppers, Latalus sayi, Endria inimica and Draeculocephala antica, were reared in the greenhouse on a mixture of timothy, brome, and orchardgrass. A few Dryinid parasites, Chalcogonatopus sp. were maintained on the L. sayi and E. inimica during this time.

At Tifton, Ga., 4, 8, and 16 spittlebug adults, feeding on Coastal bermudagrass in the greenhouse, inhibited root development. Untreated plants produced more than twice as many roots as plants subjected to four spittlebugs per plant and more than five times as many as produced by the other two treatments. Manual defoliation of the grass gave results similar to those obtained with 8 and 16 insects per plant.

5. White-fringed Beetles. At Gulfport, Miss., the survival of newly hatched white-fringed beetle larvae was 89% greater when reared in clay pots than in plastic pots.

In studies at Gulfport, Miss., a diet consisting of 10 gm freeze-dried peanut leaf meal, 5 gm NBC Vitamin fortification, 5 gm agar, 1.0 ml formalin, and 200 ml distilled water, was tested as an adult diet for the white-fringed beetle. Good adult longevity and egg production were obtained.

Under a grant to Auburn University, it was found that mold inhibitors used in artificial diets were lethal to white-fringed beetle larvae. The most successful rearing procedure was to use sprouted Irish potatoes.

B. Insecticidal and Cultural Control

1. Grasshoppers. Field tests were conducted at Bozeman, Mont., to establish effective dosages of insecticides applied by aircraft as ultra low volume sprays to control grasshoppers on rangeland. The indicated dosage for Bay 39007 was 8 oz actual per acre; for Mobil MC-A-600 5 oz, and for diazinon 10 oz.

Two experiments were conducted in Montana with technical malathion applied by aircraft at ultra low volume (8 oz fluid/acre) to control grasshoppers. One compared fine and coarse spray applied from different heights. From a height of 200 feet fine spray was found significantly inferior to coarse spray. There was no significant difference between treatments (1) fine at 50 ft, (2) fine at 100 ft, (3) coarse at 100 ft, and (4) coarse at 200 ft. The spray classed as coarse with a volume median diameter (vmd) of 278 u was recommended over fine spray with a vmd of 135 u. Individual plot data indicated that the coarse spray applied from 100 ft would give the best results under a variety of field conditions. In the second experiment, 0.1 inch of moisture, applied to malathion-treated plots immediately prior to and at intervals of two and eight hours after treatment, showed no significant effect on control. These results were further substantiated by observations on the effect of natural rainfall and dew; however, it is pointed out that field experience has shown that rainfall reduces the effectiveness of malathion.

2. Alfalfa Insects. Twenty-one new candidate insecticides were screened at Beltsville, Md., against adult alfalfa weevils, and five gave lower LC_{50} values than the standard azinphosmethyl. These were fenthion, CIBA C-9643, Hercules 9007, Shell SD-14045, and Vero Beach Bay 77488.

Phorate, parathion, and carbaryl were applied in granular form to five-acre plots of dormant alfalfa both in late fall and early spring in central Maryland for alfalfa weevil control. Phorate gave significantly better results than the other two and might provide adequate control in normal years. At the rate of 2 pounds per acre in the fall, weevil adults were reduced about 85% and foliage damage was reduced about 60%. At the rate of 1 lb per acre in the spring, weevil adults were reduced about 89% and foliage damage was reduced about 84%. Niagara NIA-10242 applied to 1/2 acre plots gave 67% (fall application) and 97% (spring application) control based on foliage damage at time of harvest.

A comparison of the commonly recommended insecticides applied to the growing crop showed that methoxychlor (1-1/2 lb per acre) gave better control of weevil larvae than Imidan, parathion, azinphosmethyl, malathion, and carbaryl. However, methoxychlor was significantly better in only one of four comparisons.

At Beltsville, Md., six experimental insecticides applied at comparable dosage rates to small plots gave better control of weevil larvae than the

check, azinphosmethyl. In descending order of effectiveness they were: Niagara NIA-10242, Union Carbide UC-34096, Dursban, CIBA C-9643, Shell SD-14045, and Hercules 13462.

At Lincoln, Nebr., dimethoate, endosulfan, ethion, toxaphene, General Chemical GC-6506, and DDT were tested against the tarnished plant bug, L. lineolaris, and the alfalfa seed chalcid, Bruchophagus roddi. Nymphs of the tarnished plant bug were initially controlled by all the compounds. None of the compounds provided satisfactory initial control of adults. DDT provided the greatest degree of residual control against this species. The alfalfa seed chalcid was not controlled by any of the insecticides. None of the insecticides significantly increased seed yields.

3. Grass Insects. DDT, malathion, and diazinon were evaluated at Lincoln, Nebr., for the control of the bromegrass seed midge. A reduction in the number of adult midges was evidenced only after repeated applications.

At Tifton, Ga., application of insecticides to the soil surface of millet fields killed large numbers of mole crickets, reduced loss of plant stand, and increased yield of forage. Stauffer N-2790 bait, Kepone bait, Stauffer N-2790 granules and/or Mobil MC-A-600 granules, and trichlorfon granules performed best in the order given.

At Tifton mowing Coastal bermudagrass fields infested with two-lined spittlebugs drastically reduced the numbers of nymphal masses and was the best control method for nymphs. Azinphosomethyl and carbaryl at 1.5 kg/hectare controlled nymphs and adults on Coastal bermudagrass. Malathion, diazinon, and Dibrom at the same rate controlled adults but not nymphs.

4. White-fringed Beetles. Laboratory tests were conducted at Gulfport, Miss., with 18 insecticides as foliar sprays at 1/2, 1, and 2 pounds per acre, to control white-fringed beetle adults. Twenty adult beetles were caged on the foliage after spraying and mortality counts were made after a 48-hour exposure period. Dursban and Bay 78182 were the most promising at all three levels. American Cyanamid 43913 and Shell SD-8280 gave good control at the 1- and 2-pound rate.

Twenty-nine compounds were tested against newly hatched white-fringed beetle larvae. Soil was treated with these compounds at 1, 5, and 10 pounds per acre, placed in flower pots and infested with newly hatched larvae in August. The soil was examined for larvae from November to January. At the 5- and 10-pound rates, isobenzan, nonachlor, nirex, Bay 77488, Dursban, Compound 4072, Stauffer N-2790, and Mobil V-C 3-668 gave control comparable to that of DDT.

White-fringed beetle larvae collected in a treated nursery near Gulfport, Miss., and analyzed by gas chromatography contained DDT and dieldrin. Soil samples taken at the same location also showed the presence of these insecticides. Laboratory reared larvae and field collected larvae from

non-treated areas did not show any insecticides. This might help to develop a quick method of determining resistance to insecticides.

C. Insecticide Residue Determinations

1. Niagara NIA-10242. At Tifton, Ga., plots of silage corn were treated with NIA-10242 wettable powder at rates of 0.25, 0.50, and 1.00 pounds per acre and the corn ensiled the following day. Initial residues of NIA-10242 in corn were about 9.8 ppm. The residues declined in the field, but in silage the level remained rather constant. No phenolic hydrolysis product was detected in the corn from the field or in the silage. No residues of NIA-10242 or its phenolic hydrolysis product were found in milk from cows fed the treated silage. Cholinesterase activity of the blood from the animals fed the treated silage appeared unaffected.

Initial residues on Coastal bermudagrass treated at Tifton, Ga., with NIA-10242 at 1 pound per acre were 24.1 ppm of NIA-10242 and 0.23 ppm of its phenolic hydrolysis product. After weathering in the field for 14 days, no residues of either compound could be detected.

2. MC-A-600. Samples of Coastal bermudagrass, silage, and milk from animals fed treated silage from a study conducted at Tifton, Ga., in 1965 were reanalyzed by a sensitive and specific gas chromatographic procedure for MC-A-600 and its phenolic hydrolysis product. No trace (less than 0.01 ppm) of MC-A-600 or its hydrolysis product was found in the milk. Samples of grass treated with 2.0 pounds per acre taken the same day as application contained 38.7 and 1.20 ppm of MC-A-600 and its phenolic hydrolysis product, respectively. Silage 66 days old prepared from this grass contained 29.0 and 4.05 ppm of MC-A-600 and its phenol.

3. Imidan and Imidoxon. At Tifton, Ga., samples of soybeans, corn, and Coastal bermudagrass treated with Imidan at 0.25, 0.50, and 1.0 pound per acre were analyzed by gas chromatography. In all cases the Imidoxon residues were very low compared to those of Imidan. On Coastal bermudagrass the initial residues of Imidan averaged 12.3 ppm for the 0.25 pound per acre treatment, 27.0 ppm for the 0.50 pound treatment, and 52.0 ppm for the 1.00 pound treatment; the Imidoxon residues initially were 0.06, 0.13, and 0.36 ppm, respectively. Fifteen days after treatment the Imidan residues averaged 0.13, 0.36, and 0.57 ppm and no Imidoxon residues were detected. On corn the initial residues of Imidan were 2.67, 7.07, and 10.9 ppm, and those of Imidoxon 0.00, 0.01, and 0.02 ppm. Seven days after treatment the Imidan residues on corn were 0.09, 0.26, and 0.63 ppm and no Imidoxon was detected. On soybeans the initial residue of Imidan were 31.2, 55.4, and 82.2 ppm and those of Imidoxon were 0.03, 0.07, and 0.11 ppm. Fifteen days after treatment with Imidan residues were 0.10, 0.28, and 0.76 ppm and no Imidoxon was detected.

In another study at Tifton, cows were fed for 42 days on corn silage to which about 19 ppm of Imidan (dry basis) had been added. Analysis showed no detectable residues of Imidan or Imidoxon in the milk. No residues were

detected in samples of urine or feces taken 31 and 35 days after feeding was started. Blood cholinesterase activity of the animals appeared to be unaffected during the test period.

4. Dimethoate. At Beltsville, Md., corn was treated with dimethoate at rates of 32 and 8 oz per acre, harvested, chopped as silage, and samples taken for residue analyses. After one day samples from the 32-oz treatment contained an average residue of 7.0 ppm of dimethoate and about 0.2 ppm of the oxygen analog. In the 7-day samples the average dimethoate residue was 0.19 ppm and no oxygen analog was detected. The one-day samples from the 8-oz treatment contained an average residue of 1.27 ppm of dimethoate and less than 0.01 ppm of the oxygen analog. In the 7-day samples the average dimethoate residue was 0.53 ppm and less than 0.01 ppm of oxygen analog was present.

5. Bidrin and Azodrin. Milk from cows at Tifton, Ga., fed corn silage containing about 19 ppm of Bidrin (dry basis) for 28 days contained no detectable residues of these compounds. Urine taken during the same interval contained from 0.01 to 0.20 ppm of Bidrin and 0.134 to 0.268 ppm of Azodrin. Blood cholinesterase activity of the animals decreased as much as 50% during the test.

6. Dursban. Plots of corn and Coastal bermudagrass at Tifton, Ga., were treated with Dursban emulsifiable concentrate at 1.0 pound per acre. Samples were taken immediately after application and at intervals up to 21 days for the grass and 14 days for the corn. Samples of jar silage one month old prepared from the two treated crops also were analyzed. Analyses were made by gas chromatography. Immediately after application an average of 13.2 ppm of Dursban (on wet basis) and 0.12 ppm of the oxygen analog was found on the grass; 21 days later these levels had declined to 0.18 ppm and less than 0.004 ppm, respectively. On the corn the average initial deposits were 5.60 and 0.044 ppm, declining to 0.415 and 0.006 after 14 days. The levels of Dursban and its oxygen analog in the jar silage averaged 8.72 and 0.258 ppm, respectively, in the grass, and 3.10 and 0.037 ppm in the corn.

At Tifton, Ga., milk from cows fed Dursban at the rate of 0.65 mg/kg of body weight for 10 days contained trace amounts of Dursban (0.001 to 0.003 ppm). The oxygen analog of Dursban was not detected.

7. DDT. At Yakima, Wash., vegetation from upland meadows within the Burns tussock moth project was analyzed for DDT, which had been applied one year earlier by helicopter at the rate of 0.75 pound per acre. The average residues (ppm) of DDT isomers plus metabolites on a dry-weight basis for each type of vegetation were: sedge 2.07; lupine 0.41; sagebrush 1.22. Pretreatment samples of sedge contained 0.16 ppm and those of lupine and sagebrush each contained 1.4 ppm.

D. Biological Control

1. Grasshoppers. In 1966 natural enemies, mostly birds and dipterous larval parasites, were abundant and destroyed many grasshoppers in some areas of Arizona. At San Carlos in late September adults of Trachyrhachys mexicana were parasitized 25% by nemestrinid flies and at San Rafael Valley average parasitism of adult Morseiella flaviventris and Boopedon nubilum grasshoppers by nemestrinid larvae at five stations was 21.3% on September 7.

Four species of Protozoans and two viruses of grasshoppers are under study. Nosema locustae, a microsporidian, infects the fat bodies causing reduced fecundity and increased mortalities. N. acridophagus, another microsporidian, attacks various tissues of the host induces tumors and is highly virulent. Nosema n. sp. is a microsporidian, recently isolated, which infects the fat bodies of grasshoppers but is more virulent than N. locustae, probably because of a shorter life cycle. This organism is being studied in the laboratory. Malamoeba locustae, an amoebic protozoan, infects the midgut Malpighian tubule epithelia. This organism is not highly virulent to grasshoppers but does reduce vitality and fecundity. The two viruses appear very promising for use against grasshoppers. The inclusion body virus, which was isolated two years ago, infects the fat bodies and pathologically is quite similar to N. locustae. The non-inclusion body virus was isolated about one year ago and is still undergoing extensive laboratory investigations. This virus is highly virulent, infects the muscles of the host, causing 50% mortalities among nymphs in a period of five days.

Research is now underway under a cooperative agreement recently made with the University of Montana to study the lipid characterization of grasshopper fat bodies in relation to infection by the pathogen, M. locustae.

Under a grant to the University of Montana, a polyhedrosis virus (PV-1) and a non-inclusion virus (CV-1) isolated from grasshoppers are being studied. PV-1 affects the fat bodies and CV-1 the muscle tissue. These viruses have been partially purified by a sucrose density gradient ultracentrifugation technique and some of the physical and chemical properties determined.

2. Alfalfa Insects. A four year study at Lincoln, Nebr., on the parasitism of the alfalfa weevil in the area immediately east of the Rocky Mountains showed that the parasite, Bathyplectes curculionis, was easily detected wherever weevil larvae were collected. The highest rate of parasitism was 94%, but the rate of parasitism and magnitude of weevil populations fluctuated greatly. The relationships between these fluctuations are not clarified by the data but it is felt that the eastward spread of the weevil may be slowed by the parasite.

Bathyplectes anurus, a larval parasite of the alfalfa weevil, was released in Maryland for the first time in 1967. The incidence of B. curculionis and Tetrastichus incertus, the two widely distributed larval parasites in Maryland and New Jersey, was generally lower in 1967 than in 1966. The highest rate of parasitism by B. curculionis in survey fields was 15% in a New Jersey field and 3% in a Maryland field. Parasitism of larvae collected from fields on the Eastern Shore of Maryland was much higher - exceeding 40%. T. incertus occurred commonly in June when host populations were low, as usual. The adult parasite, Microctonus sp. "black" was recovered from a Beltsville field.

At Mesa, Ariz., nearly 1000 adults of Peridesmia discus, an egg parasite of the Egyptian alfalfa weevil, were released in February and nearly 2000 adults of Tetrastichus incertus, a larval parasite, were released in March 1967. From February to April B. curculionis, another larval parasite of this weevil, was found in several fields and parasitism ranged from 2 to 30%.

A research grant was recently awarded to the University of Kentucky to study the bionomics of Aphidius smithi, a parasite of the pea aphid, and to determine the effect of insecticides applied to alfalfa on this parasite.

3. Grass Insects. A parasitic Hymenoptera, identified as an apparently undescribed species of Tetrastichus has been found associated with brome grass heads in Nebraska for a number of years. During the summer of 1966 it was determined by laboratory rearing that this Hymenoptera is a parasite of the brome grass seed midge. The rate of parasitism was as high as 96% by mid-July.

At Weslaco, Tex., under a grant with the Texas Experiment Station, it was shown that air releases of grass infested with the Rhodesgrass scale parasite, Neodusmetia sangwani, at intervals of 1x1 or 1x2 miles was more effective than 2x2-mile intervals. The yield of grass (dry weight) in the biocontrol plots was 1851 pounds compared with 1021 pounds per acre in the check plot.

4. White-fringed Beetles. At Gulfport, Miss., 200,000 active DD-136 nematodes were applied to balled and burlapped and potted nursery plants infested with 20 field collected white-fringed beetle larvae each. Complete control was not achieved in any test.

In a survey to find naturally occurring diseases of the white-fringed beetle, over 2500 larvae have been received at Gulfport for examination. None were infected with parasitic nematodes. Several dead larvae were infected with a red bacterium.

Thuricide, Mattesia grandis, and nematode DD-136, tested as a dip and spray on peanut foliage treatments failed to control white-fringed beetle adults.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. White-fringed Beetles. In olfactometer tests at Gulfport, Miss., 35 materials were screened against white-fringed beetle larvae and 59 against the adults. None of them showed attractancy to the beetle.

A cooperative agreement was recently initiated at the University of Georgia to evaluate plant extracts and synthetic compounds as attractants for the white-fringed beetle.

2. Alfalfa Insects. The ovipositional responses of the alfalfa seed chalcid to chemicals occurring in alfalfa is being studied under a grant to the University of Wyoming. Of 81 chemicals tested 23 elicited a response when brought into contact with the ovipositor. Citric acid lineoleic acid, oleic acid, maltose and vitamin D₂ were among those chemicals causing a reaction.

At Blacksburg, Va., under a contract with Virginia Polytechnic Institute, an extract of alfalfa prepared with hot NaCl was more attractive to the alfalfa weevil than 14 other compounds. It was broken down into six fractions, two of which were quite active. In this same study apholate effectively sterilized the alfalfa weevil when both sexes were treated, but after 4-8 weeks the weevils began to regain their ability to reproduce.

F. Evaluation of Equipment for Insect Detection and Control

Research at Beltsville, Md., with liquid propane flammers to control the alfalfa weevil showed that flaming dormant alfalfa in March gave control essentially equal to that obtained with a standard insecticide application of methoxychlor-malathion. However, due to the abnormally early and extended period of larval damage, two treatments were necessary to protect the crop: either flaming plus an insecticide application prior to harvest, or two insecticide applications (one prior to harvest and one to the stubble following harvest).

G. Varietal Evaluation for Insect Resistance

1. Alfalfa Weevil. Definite progress was made at Beltsville, Md., in selection for an intensification of plant resistance to the alfalfa weevil. Most of the plant material was tested in several groups or populations of similar genetic make-up, such as winter hardiness and disease resistance. Seedling populations from intercrosses of selected clones are subjected to adult feeding until only 1-2% remain. These survivors are then subjected individually to larval survival, adult leaf feeding, and oviposition tests. Selections within each population is then intercrossed again for the next cycle of selection.

A total of 116 plants were selected from old-field stands of alfalfa in Maryland as a possible source of resistant germ plasm. A group of 12 clones showing extremes of susceptibility or resistance were selected for use as

checks in the laboratory screening program, in special laboratory studies, and in large-cage field studies.

At University, Park, Pa., an alfalfa nursery of 407 introductions was evaluated for alfalfa weevil damage in 1966. Differences in amount of feeding were present, but none of the plants was considered outstanding.

A research contract (jointly with Crops Research Division) was recently initiated with the Research Triangle Institute, Research Triangle Park, N. C., to study the relationship of alfalfa saponins to insect resistance.

2. Spotted Alfalfa Aphid and Pea Aphid. Tests at Lincoln, Nebr., with the pea aphid to determine its preference for detached leaves from susceptible and resistant alfalfa clones were conducted in environmental chambers at temperatures of 50° and 80° F. Analysis of variance showed that there was no interaction between the temperatures and the clones. However, the pea aphid at both temperatures preferred the more susceptible clones.

Experiments were conducted at Lincoln to determine the preference of the spotted alfalfa aphid on susceptible and resistant clones of alfalfa at 50° and 80° F. At 50° F there was generally less preference by the aphid for susceptible clones than at 80° F. The aphids exhibited a strong non-preference for certain resistant clones at both temperatures.

At Tucson, Ariz., 25 alfalfas and experimental lines, developed cooperatively by plant breeders and entomologists, were evaluated for resistance to the pea aphid and two biotypes of the spotted alfalfa aphid. Seedling survival ranged from 46 to 95% for entries tested against biotypes ENT-A and ENT-B of the spotted alfalfa aphid and 32 to 93% for entries tested against the pea aphid. Four experimental lines had 90% or better seedling survival against ENT-A whereas the check (Moapa) had only 46%. Five entries had 90% or better seedling survival against ENT-B whereas the check (Moapa) had 65%. Two entries had more than 90% seedling survival against the pea aphid.

At Reno, Nev., research under a cooperative agreement (jointly with Crops Research Division) showed that pea aphids exhibited a decided preference for an artificial diet to which steam distillates from a susceptible alfalfa variety were added. Pea aphids have been maintained as long as 32 days when fed through a membrane on an artificial diet.

At Tucson, Ariz., five alfalfas and experimentals were evaluated in greenhouse tests for resistance to the pea aphid and ENT-A and ENT-B of the spotted alfalfa aphid. An experimental, M-56-11 T.C., was rated as having the tallest plants and the highest percent of seedling survival against both species of aphids. Percent seedling survivals were 98, 96, and 68 against ENT-A, ENT-B, of the spotted alfalfa aphid, and the pea aphid, respectively, compared to 40, 50, and 40% survival for the check variety, Moapa.

At Tucson, Ariz., several hundred alfalfa plants were screened for resistance to the pea aphid and ENT-A of the spotted alfalfa aphid, and released to plant breeders. For Arizona breeders, 700 progenies from 59 two-clone combinations involving material from Mesa-Sirsa were screened for resistance to the pea aphid. For California, over 100 plants each from experimentals SW-28, SW-30, SW-31, and SW-42 were selected for resistance to both species of aphids. For Nevada, over 100 plants each from MSE and MSF were selected for resistance to both species of aphids.

At Mesa, Ariz., about 200 plants from different sources having root-rot tolerance were selected for resistance to ENT-A biotype of the spotted alfalfa aphid.

In a contract to Kansas State University to develop alfalfas with resistance to two or more insects, 32,670 seedling plants from intercrossing 73 spotted alfalfa aphid resistant plants and 84 pea aphid resistant plants were exposed to both aphids and 5,200 survived the test. Of 856 Cody x DuPuits plants cage tested, 365, 327, and 227 were resistant to the spotted alfalfa aphid, pea aphid, and both aphids, respectively.

3. Alfalfa Seed Chalcid. At Mesa, Ariz., progenies from a 22-clone synthetic were screened for resistance to field populations of the alfalfa seed chalcid. Among 90 plants screened from a total of 1400 progenies about half of them had a high level of resistance following greenhouse cage tests. Thus, the process of recycling and reselecting gave about 40-fold increase in the number of chalcid resistant plants.

4. Lygus Bugs. Several thousand plants representing progeny from Sirsa #9 were screened in field tests at Mesa. Thirteen plants were selected that were free from lygus damage. All material has been increased by propagation and prepared for antibiosis cage tests.

Research under a grant to Kansas State University showed that seed from alfalfa plants that survived severe lygus bug attack gave rise to plants more resistant than the population from which they were selected. Seed of 29 surviving plants sib pollinated within varieties produced plants that showed 17 lines were superior to their parents.

5. Leafhoppers. Twenty-two plants from Moapa alfalfa were selected for high tolerance to the leafhopper, Empoasca abrupta, from 3-year old plantings at Mesa, Ariz.

Five hundred and fifty plants in the 1966 potato leafhopper observation alfalfa nursery were evaluated at Lincoln, Nebr., and 68 clones having apparent leafhopper resistance were tested for resistance to both the pea aphid and spotted alfalfa aphid. Nineteen of the 68 plants were classified as having antibiosis resistance to both aphid species. These 19 plants were retained for use in the alfalfa breeding program to develop improved experimental synthetics with combined resistance to these three insect species.

6. Grasshoppers. Studies at Bozeman, Mont., on resistance of forage plants to grasshopper feeding showed that of eight plant species, green needlegrass, thickspike wheatgrass, and bluebunch wheatgrass were least preferred by adult migratory grasshoppers. The adults also gained the least weight and deposited the fewest egg pods when they were fed the least preferred plants.

7. Sweetclover Aphid. The great majority of evidence obtained at Lincoln, Nebr., from a study of the inheritance of resistance to the sweetclover aphid in yellow-flowered sweetclover indicated resistance was governed by a single gene pair with resistance dominant. However, the segregation resulting from certain individual crosses indicated that complimentary genes were present. Assuming complimentary genes, all data obtained that gave a satisfactory fit to a single gene hypothesis would be expected if one of the interacting gene pairs was homozygous dominant in both parents while the second allelic pair was segregating.

8. Sweetclover Weevil. Studies are underway at Lincoln, Nebr., to locate a source of resistance to the sweetclover weevil that would be as effective as Melilotus infesta, but which could be more readily crossed into the commercial types of sweetclover. Twenty-four recent Melilotus introductions were screened for weevil resistance during the 1966-67 greenhouse season. None of them were uniformly resistant, but individual plants appearing to have some degree of resistance were selected from some of them.

Under a grant to the University of Nebraska (jointly with Crops Research Division) a feeding stimulant and a deterrent have been found in sweetclover species resistant and susceptible to the sweetclover weevil. A second deterrent has been found in M. infesta which may account for the near immunity of this species to weevil feeding.

9. Grass Insects. At Tifton, Ga., a laboratory technique was developed to screen bermudagrass introductions and hybrids for resistance to newly hatched fall armyworm larvae. This technique detected differences between the grasses and also proved that first instar larvae eat only tender leaves and refuse sections from older leaves.

At Tifton 120 clones of Coastal bermudagrass were each infested with approximately 500 first instar larvae of the fall armyworm. Of the clones evaluated, 118 showed a high level of susceptibility to larval feeding. Two entries (Tifton Nos. 76 and 165) were less preferred for larval feeding indicating that hybridization and selection might be used to obtain genotypes having greater resistance.

At Tifton over 400 bermudagrasses were screened in the field for resistance to adult two-lined spittlebugs, and seven plant introductions (Tifton field numbers 36, 88, 390, 395, 401, 543, and 581) consistently received low damage ratings.

Over 1200 pearl millet inbreds were screened for resistance to fall army-worm larvae. Inbreds 153, 192, 266, 555, and 756 (Tifton numbers) have exhibited high resistance in repeated testing. There are indications that the biology of larvae is adversely affected when worms are forced to feed only on resistant plants. The weight gain of larvae fed only on a highly preferred inbred significantly exceeded that gained by larvae confined to a resistant inbred.

H. Insect Vectors of Diseases

Red Clover Virus. The clover root borer, Hylastinus obscurus, often associated with the occurrence of virus in the field, is being investigated at University Park, Pa., as a possible vector. Findings have been complicated by an unexplained development of virus in the test plants. A greenhouse sanitation program has been initiated in an effort to rectify the problem.

Research studies in Poland under P.L. 480 project E21-ENT-9 to study the vectors of virus diseases of legumes was completed in January 1967. Of greatest significance was the finding that the green peach aphid and the pea aphid could simultaneously transmit more than one legume virus.

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PRODUCTION, HARVESTING AND FARM STORAGE STRUCTURES,
EQUIPMENT AND METHODS
Agricultural Engineering Research Division, ARS

Problem. Better methods, techniques, equipment and structures for use on the farm for producing, harvesting, storing, and the initial preparation of grain, seed and forage crops for market are needed to increase efficiency in the use of labor and equipment, preserve quality and prevent spoilage and damage from mechanical handling and insects. Electromagnetic energy has many established farm uses but research indicates other highly useful potential capabilities in farm production, such as attracting and killing insects and improving the germination of seeds. There is considerable present need for precise seedbed requirements for various crops in different areas of the country. The exact best placement for starter fertilizer is also unknown for a number of crops under different climatic and soil conditions. Every method to control or eradicate plant diseases, weeds, and insects requires some type of equipment. Effectiveness of the equipment necessary may be essential to the success of the method which is attempted or recommended. The cost of harvesting and farm handling of forage, grain and seed crops is the major expense of production. The supply and adequacy of manpower for these operations are becoming progressively less satisfactory, thus requiring additional research in this area. While considerable information has already been obtained for the development of processes such as drying and separation, basic and more precise information must be developed for these and other processes in order to achieve further progress. New trends in storage structures also require additional research in design and use.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, statisticians, physicists, and architects engaged in both basic and applied research in this area. Cooperation is maintained with experiment stations, the farm equipment industry and other scientific disciplines in the Department. The total effort involves 18.0 scientist man-years. Of this number, 2.0 are devoted to the use of electrical energy, 1.4 to equipment for establishment of forages, 2.9 to weed control in corn and soybeans, 2.3 to insect control in grain, 1.0 to corn harvesting equipment, 0.3 to forage harvesting equipment, 1.5 to forage seed harvesting equipment, 2.0 to grain drying, 1.2 to forage processing, 2.5 to seed cleaning, and 0.9 to crop storage structures. Research is carried on at Beltsville, Md., Athens, Experiment and Tifton, Ga., Ames, Iowa, Lincoln, Nebr., Corvallis, Ore., Lafayette, Ind., Bushland, Tex., Manhattan, Kans., Wooster, Ohio, and Knoxville, Tenn.

PROGRAM OF STATE EXPERIMENT STATIONS

Many of the State agricultural experiment stations are engaged in both fundamental and applied research dealing with the development of new principles and the application of currently available knowledge to the problems concerned in soil-machine relationships in order to increase efficiency in crop production. These studies are concerned in the broadest sense with the development of theories, special devices, and laboratory and field tests to determine ways in which tractive and transport equipment, tillage tools and systems for their use might be improved.

Problems concerned with planting of the many sizes and shapes of seed together with the introduction of fertilizers are under attack by many of the State agricultural experiment stations. These studies are concerned with the development of new principles that can be used to meter and place seed which could lead to planter improvement. Similar investigations are in progress to develop satisfactory metering and placement devices for application of liquid as well as solid fertilizers. In both instances the principal objective is to provide the best possible means of seed and fertilizer placement which will assure healthy plant emergence with vigorous growth to maturity.

Both basic and applied research investigations which have been designed to discover and develop methods, techniques, and equipment for control of the many pests that attack grain and forage crops are in progress at the several agricultural experiment stations.

Most of the State agricultural experiment stations are engaged in some aspect of basic or applied research which is concerned with improving machines and methods for efficient harvesting and farm handling of grain and forage crops. Detailed investigations are in progress to develop reliable mechanical harvesting and handling equipment as well as ways in which improvements might be made in crop production systems to increase yields, product quality and overall efficiency.

Many freshly harvested agricultural crops must be subjected to early treatment in order that they may retain as much as possible of their original qualities. The State agricultural experiment stations are involved in both basic and applied research studies which have as their broad objectives the development of improved methods, equipment and techniques for preparation and processing of farm crops to preserve quality and prevent spoiling while in storage.

The complicated problems associated with providing protection to the products of agricultural production as well as the machines, equipment and service facilities which are required for such production has necessitated

a continuing program of research at the State agricultural experiment stations. The current program is concerned with conditioning and storages for high moisture grains; structural characteristics, wall pressures, design and construction of silos; controlled atmosphere storages and construction methods; and designs and construction of plant growth chambers and plastic greenhouses.

Several of the States are engaged in programs of basic and applied research on the possible use of some of the various forms of electrical and physical energies as a means for improvement of the potential capabilities in farm production. Investigations in progress include the evaluation of the use of radiofrequency energy for treatment of grains to destroy insect infestation and treatment of seeds to improve their germination characteristics.

The agricultural experiment stations of many of the States have research under way whose major objectives involve the obtaining of information on the uses to be made of electrical energy to reduce labor, increase production and improve family living conditions. In the design of these studies provision has been made to develop and investigate new equipment and explore the possibilities for new uses for electricity on the farm. Many of the projects are concerned with the varied problems of chore labor mechanization and an expansion of the use of electricity for ventilating, heating, lighting and cooling under the various production enterprises of today's farming operations. Development and testing of prototype specialized equipment for product collection, processing, packaging, and transport, as well as crop storage, loading devices, are a part of the overall program of investigations.

The State agricultural experiment stations are engaged in extensive basic and applied research to extend the advantages of controlled environment to all phases of agriculture in order to obtain maximum economic growth, production, product preservation and product quality. Studies of the possibilities for use of solar energy as well as electric energy to achieve the broad scale objectives are a part of the total program. Among the several investigations involved in these programs are determination of the effects that soil, light and atmospheric conditions on plants; and temperature, humidity and gases on stored products. Special attention is being given to development of means for collection, storage and use of solar energy for crop conditioning.

Much of this research is cooperative with the Department.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Equipment for Establishment of Forages.

1. In studies of methods of establishing Coastal bermudagrass, ratings of plots the second year are listed by treatments in order of effect (best treatment first): (1) herbicides after sprigging (with good moisture), (2) water with sprigs, and (3) precision placement of fertilizer. Water with sprigs was much more beneficial when no herbicides were used and a poor growing season (scant moisture) was encountered. Four specially designed machines were provided, the special grassland drill used with the rye grass-oats experiment was redesigned, and a new pasture machine was started for the fescue and rye interseeding in Midland bermudagrass.

In Maryland, crownvetch seeded into bluegrass pasture without tearing up existing plants, produced yield increases equal to complete renovation of pasture to orchardgrass-ladino clover. Birdsfoot trefoil seeded into the same pasture increased yields but significantly less than crownvetch or complete renovation. Earlier research cooperative with the Maryland station demonstrated that the production of Midland pastures can be nearly doubled by seeding cool-season annuals into the existing sward. Preliminary new data indicate that the seeding of cool-season perennials is no more productive than the annuals and much more difficult to manage.

Cooperators at the Western Washington experiment station, using placement machines designed and constructed by AE, found that the mean yield of timothy from the 30-inch spaced band-fertilized rows exceeded that of the 7-inch broadcast fertilized rows by over 100 percent. Rates of N application varied from 0 to 120 pounds per acre. Similar results were obtained with orchard grass. Also compared were the effects of a complete fertilizer (80-80-80 lbs. per acre) applied at one of three different dates, approximately August 1, September 1, and March 15. Both 7-inch spaced rows with broadcast fertilizer and 30-inch rows with band fertilization were tested. Yields of timothy in 30-inch rows were higher for September fertilization than for either August or March. Mean yields of timothy and orchardgrass were greater by more than 100 and 60 percent, respectively, when seeded and fertilized in 30-inch rather than 7-inch rows. At Big Spring, Texas on Amarillo sandy clay loam the seedling survival of certain grasses was evaluated after three variations in soil tillage: deep plowing, normal field density, and compacted. Chiseling to a 30-inch depth with a vibrating chisel was applied to one half of the "normal field density" and "compacted" plots. Greatest seedling survival was from plantings in the normal field density plots, and very little effect was observed from the deep vibrating chiseling.

2. Research under contract with the New Mexico station has developed equipment which will operate with a plow and seeder to place plowed up brush on the seeded strip during one pass over the rangeland. Previous research by ARS has shown that a relatively sparse cover of brush is effective in cooling the ground and conserving moisture. This favors germination of seeds and plant emergence in arid areas. Two types of equipment have been designed and tested: a side delivery windrower, and an endless chain conveyor which lifts the brush residue over trailing seeding equipment and drops it on the seeded strip behind the planter. The side-delivery equipment was tested during planting tests in 1966 on several types of soils. Additional shielding equipment was found to be necessary to guide and place the brush residue onto the seeded strip. Preliminary field trials with the endless chain conveyor have been satisfactory and it is considered to be the better of the two types of equipment.

B. Insect Control in Grain.

1. Investigations for the control of the European corn borer, made in cooperation with the Iowa station, indicated that recommended rates of granular insecticides in pounds per acre gave adequate corn borer control regardless of plant spacing. Granular formulations continued to show better borer control than liquids. Granular insecticides at cultivation time resulted in good control of both corn rootworms and corn borers. Soil incorporation improved the rootworm control, but the kinds of tools used for incorporation or the amount of soil worked had little effect on control. Granules applied directly over the corn plant (recommended for borer control) were as effective for rootworm control as basal applications. Granular and liquid application equipment was modified to fit both 30-inch and 20-inch row widths.

High-clearance spray equipment was used to apply insecticides for the control of the adult corn rootworm in cooperation with the Ohio Station. High initial kills were obtained. Reinfestation apparently nullified this effect. Diazinon, carbaryl, and methyl parathion gave the highest initial adult kill. Single and repeated applications made in timing studies between August 15th and 22nd did not produce significantly different results. Sprays applied to corn for flea beetle control gave significant reductions of infestation. Methyl parathion gave the greatest initial and residual reduction in beetle population but increases in corn yield were not significant.

2. An experimental low-volume sprayer was developed in Georgia which can apply one pint to one quart per acre. Using this sprayer on corn and soybeans produced results that compared favorably with those obtained from conventional spraying. A special fan trap was superior to a gravity trap when collecting eight species of insects. A field insect collector was developed for cooperating entomologists, and a Lepidopterous Larvae Dispenser for use in mass rearing of larvae for experiments. The use of ultrasonics appeared ineffective for control of the corn earworm. Orienting seed at planting did not improve insect control in corn.

C. Weed Control in Corn

Several systems of mechanical cultivation were evaluated for weed control in corn, in cooperation with the Iowa station. A dragging rotary hoe used to till a band 15 inches wide over the corn row was more effective than the rotary hoe. Harrowing after planting improved weed control best of all mechanical cultivating systems used. Shallow cultivations (rotary hoe or dragging hoe) when performed separately were most effective when weeds were at the two-leaf stage. A dragging hoe used with the first sweep cultivation (4- to 8-leaf stage) eliminated the need for early shallow cultivations. Weeds in the row must be controlled if maximum yields are to be obtained.

Equipment studies, in cooperation with the Missouri station, show that dalapon can be applied on corn if nozzles are arranged to prevent the spray from contacting the corn leaves. Linuron (two pounds per acre) was more effective with a directed sprayer when the corn was 12 inches high. Dinitro (three pounds per acre) can be used as a postemergence herbicide in six-inch high soybeans if spray is directed to the lower stems of the plant. Preemergence herbicides applied in eight-inch bands are as effective as those in 16-inch bands. In low volume preemergence applications (.5 to 5 gpa) of herbicides, trifluralin is more effective than amiben, and an air atomizing nozzle is better than a fan nozzle. Studies of spray distribution and atomization qualities of low volume nozzles showed less than five percent spray coverage, with spray losses from 10 percent to 90 percent.

Grass seed was subjected to treatment in a dielectric heater, in Mississippi, to determine effect of high frequency electric waves on germination. Frequencies of 67 to 80 megacycles and 2,450 magacycles were used. All seed was killed with exposure time of six seconds or more in the lower frequency range. No effects were observed at the higher frequency. Plans were made to treat weed seed over a wide range of frequencies of electrical waves to determine effects on germination.

2. Several herbicides were applied to field corn, in cooperation with the Iowa station, before and after planting using liquid and granular formulations that were incorporated into the soil with various tools. Chemical applications gave better weed control and higher yields than cultivated checks. Sprays were as effective as granules. Soil incorporation did not materially improve weed control with any chemicals; however, cultivating action of the incorporating tools without chemicals did improve weed control. Similar tests with soybeans showed liquids as effective as granules and weed control obtained with mechanical cultivations as good as that obtained with most chemicals.

D. Forage Seed Harvesting Equipment

1. Development of Components for Cutting, Picking up, Threshing, and Cleaning Field Seed Crops. Rotary cutter tests were continued in 1966 to develop a new method of picking up seed crops for an improved-type combine. A commercial rotary cutter was completely remodeled to increase efficiency of seed pickup and again tested in several grass and legume crops. Total seed picked up was 95.4 percent for windrowed red clover, 87.0 percent for standing red clover, 85.4 percent for windrowed creeping red fescue, 90.7 percent for windrowed Newport bluegrass, and 76.0 percent for windrowed perennial ryegrass. The best seed pickup condition was at a minimum cutter height of 0 inches but much undesirable additional material such as leaves, stems, and soil was also collected. The rotary cutter picked up a seed crop efficiently over a wide range of crop maturities but the normal combine seed pickup was greater than that for the rotary cutter when the crop was mowed at the recommended time according to standing seed moisture. No further improvements are planned. The decision whether or not to use the cutter as a component part of an improved combine will be made after other components are developed and tested.

Time-of-harvest studies have been or are being conducted on nine grass and legume crops. A new method of summarizing and showing the data for each crop on a single chart has been devised. The single chart shows an average seed moisture dry-down curve and an average pure-live-seed harvested curve as well as indicating the seed moisture and moisture drop per day at optimum mowing time.

Time-of-harvest studies were continued on bluegrass in 1966 to determine the optimum mowing time as indicated by pure-live-seed yield. The 1966 test was the fourth year for Merion and the third for Newport bluegrass. The optimum mowing time for Merion was at a seed moisture of 35 percent and for Newport--19 percent. The optimum times in 1966 were indicated by well-defined peaks on the pure-live-seed harvested curves as compared to relatively flat curves for previous tests. The data gathered on bluegrass in five years of tests was judged adequate; therefore, time-of-harvest study with bluegrass will be discontinued.

Time-of-harvest studies were continued on fineleaf fescue in 1966, for a second year, to determine the optimum mowing time as indicated by pure-live-seed yield. Both creeping red and Chewings varieties were tested. The optimum mowing time for creeping red fescue was at a seed moisture of 23 percent and for Chewings--28 percent. The optimum times in 1966 were again indicated by well-defined peaks on the pure-live-seed harvested curves. As in 1965, this harvest was five days for creeping red and six days for Chew-

ings after the farmers mowed in the same field. Time-of-harvest studies with fineleaf fescues will continue another year to gain the usual three year sequence.

Time-of-harvest studies were started on perennial ryegrass in 1966 to determine the optimum mowing time as indicated by pure-live-seed yield. The optimum mowing time for perennial ryegrass was at a seed moisture of 40 percent. The optimum time to mow precedes the time when total seed produced is a maximum because of high shatter losses. Since the optimum time of harvest was near the first cutting time, the study will continue at least another year to obtain data on the "up" side of the pure-live-seed harvested curve.

E. Corn Harvesting Equipment

1. Research was continued on the causes and effect of mechanical damage to field-shelled corn during harvesting and handling. A study of sampling methods for assaying damage done during shelling showed that manual examination, even with fast green dye, is subject to wide errors in results. Because manual examination does not dissolve the real damage done by a shelling machine, two new promising assay methods are under development. A mechanism for shelling by squeezing and rolling rather than by impact and abrasion is being tested. It operates fairly well on corn that has been held on the ear for several months, and will be ready to try on fresh-harvested corn during the fall. It is hoped that corn shelled in this way will be as sound as hand-shelled corn. Measurement of the forces required to detach the kernel, to fracture the seed coat, to deform the kernel, and to rupture the cob, indicate that the impact and abrasion typical of current shellers are not essential to separation of the kernels from the cob. They are, however, responsible for a large part of the kernel damage.

F. Seed Cleaning

1. Seed cleaning research was conducted in the attempt to improve on existing techniques for processing given seed mixtures, either by performing more precise separations with conventional equipment or by developing and using new equipment to exploit seed differences more effectively. Proper screen selection for dimensional separations was studied through measurements of seeds and screen openings. An analysis of seed dimensions (length, width, and thickness) indicated whether a screen separation was feasible, what the optimum shape and size of screen openings for making the separation should be, and the yield and purity of the final product that could be expected when a given screen was used. Experimental verification trials made with measurement-dictated screens showed a good correlation between theory and practice

in many cases, but poor correlation in others. The poor correlation was attributed mainly to sampling error, seed shape effects, and inaccurate screen holes. Seed measurements have been accumulated for many different seed types including bluegrass, bentgrass, alfalfa, cotton, fine fescue, ryegrass, timothy, corn, and others, as well as frequent contaminants found in these crop seeds. Measurements of screen openings showed many inconsistent hole sizes due to wear, dislodged wires, or manufacturing methods.

Several aspects of screening were investigated with regard to accuracy of separation. It was found that dams on screen improved separations because they interrupted the seed flow across screens, provided many orientations of seeds with respect to screen openings, and encouraged hesitant seeds to drop through the screens if dimensions permitted. This increased the accuracy in sizing or separating of seeds, and reduced seed loss. Duration of the screening process also was found important with regard to providing enough time for all potential "droppers" to find a hole and/or the necessary seed orientation for dropping. Considering the seeds capable of passing through a given screen, one minute exposure was required for 90 percent of these seeds to drop, and additional seeds were still dropping two minutes later. A comparison of hand screening and machine screening (using dams) showed that the two operations were very similar in terms of splitting the lot and dropping seeds of the same size when a long screen exposure was employed. Another screening study was conducted to establish the correlation between round and square holes that do equivalent screening jobs. Working with seed types of various shape, cross section, and size, it was found that the ratios of square holes (side dimensions) to round holes (diameters) for equivalent screening varied with the seed type and the amount of split considered for any one seed type. In general, the screening action of a given round hole was duplicated by a square hole whose side dimension was approximately 80 percent of the round-hole diameter.

Experimental equipment was developed in several instances where conventional separators could not do the required job. A catapult was devised to propel seeds through still air and take advantage of different trajectories that seeds would follow according to the resistance they encountered in flight. Tests showed some tendency for seed trajectories to differ, but results were inconsistent and good separations could not be made. A resilience separator has been constructed to investigate elastic behavior of seeds--another new, potentially useful separating basis. Several models have been built with the basic arrangement--that of dropping seeds on inclined plates and catching seed fractions at various distances from the plates. Trajectories in this development are influenced by the seed resilience. A present model with multiple glass plates has shown encouraging results in bouncing ryegrass out of orchard grass, asparagus from beets, and dirt clods from white clover.

Testing programs have been conducted with three types of conventional seed separators. The magnetic machine separates components of a seed mixture according to their surface textures and how well they pick up iron powder. This unit was tested to learn how separation efficiency was influenced by moistening liquid, type of iron powder, and additives like soluble oil or wetting agents. It was found that increased moisture (up to about one-third pound of water per bushel of seed) improved the removal of dodder and buck-horn plantain from red clover. Type of liquid was relatively unimportant, but type of iron powder was very important--the finer the powder, the better. A color sorter, that classifies material according to color or light-dark characteristics, was tested to learn its potential in separating small seeds. So far, acceptable results have been obtained in processing onion, rice, mustard, safflower, and barley. Several classes of pneumatic separators were evaluated. These machines, which separate products according to terminal velocities, were examined at two velocity ranges. The test results made it possible to rate various machines in over-all selectivity; batch separators sealed against air leakage were found more selective (as a group) than continuous flow units. Generally, the selectivity of a given separator tended to decrease as terminal velocity of the handled product increased.

2. Three types of commercial pneumatic vibrators were tested to determine their suitability for use on feeders for seed or grain. The primary consideration was delivery of a uniform flow of grain at a given setting. None of the three vibrators appeared to be well suited to the desired requirements for a feeder due to poor frequency control which governed feed rate, excessive use of air, or narrow range of controlled feed rate. Therefore, other designs will be tested. The next step in this study will be to build and test a mechanical feeder driven by a synchronous motor with the expectation that the precise control of motor and vibrator frequency will make possible a uniform feed rate.

G. Grain Drying

1. The time limitation on storing grain under any given condition is dictated by grain deterioration which is caused primarily by the growth of molds and bacteria. Of secondary importance may be the respiration or growth of the seed itself. The factors which influence the rate of growth of the microflora are grain moisture, temperature, and the amount of physical damage of the grain. It is the purpose of this study to evaluate the influence of these factors on the rate of growth of the microflora and subsequently the rate of deterioration. Continued study of carbon dioxide production in shelled corn samples verifies the damage done by field shellers. Tests started very soon after picking and shelling indicate that there may be a

short period of fast respiration immediately after picking, for both damaged and undamaged kernels; and that during this short period there is little difference in activity between damaged and undamaged kernels. Aflatoxin showed up in substantially all the samples that were held long enough at temperatures of 75° F. or higher and 23 percent moisture or higher. It is not clear just how long an exposure to these conditions is required for development of measurable aflatoxin.

H. Forage Processing

1. One year's results of the effect of irrigation of Coastal bermudagrass on processing indicate that there is no effect of irrigation on the unit processes. Although the irrigated grass appeared to have a higher yield for the season, the difference was not significant. The irrigated plots produced significantly more grass the first cutting and the non-irrigated plots produced significantly more the second cutting. For the next six cuttings, there was no significant difference. The analyses of plant constituents are not yet available. These studies will be continued.

Studies to determine the effect on processing energy for wilted millet showed that wilting for 1, 2, or 4 hours reduced the energy requirements compared to direct-cut material. The largest reduction in energy occurred in the fuel required to dehydrate. Even with wilting 4 hours, about 20 percent more fuel was required to dry the millet than to direct-cut and dehydrate Coastal bermudagrass. The analyses of carotene and other constituents for these treatments are not yet available. An empirical equation to calculate the fuel required to dehydrate millet ranging from 60 to 90 percent moisture (w.b.) has been derived.

Studies of the effect of additives on pelleting energy requirements for Coastal bermudagrass showed that cottonseed meal, cottonseed meal and ground corn, or cottonseed meal and animal fat all reduced the pelleting requirements for partially field-cured Coastal bermudagrass hay. A mixture of 10 percent cottonseed meal plus 4 percent animal fat reduced the energy requirement by about 45 percent, or about the same as for pelleting 4-week-old dehydrated hay. The addition of molasses increased the energy required when the same die was used. When the same material was pelleted through a thinner die, the energy required was only about 80 percent of that required by the check. The pellet density and durability were comparable.

A commercial, field-going hay cubing machine was evaluated as a stationary unit for Coastal bermudagrass. These tests indicated that the amount of moisture is more critical for this process than for pelleting. It appears that with a uniform feeding mechanism to allow the water added to be carefully controlled, and either a slightly longer die or one with a slight taper, the machine will produce Coastal bermudagrass cubes.

2. Preparation for evaluating the effect of processing treatments on the digestibility of Coastal bermudagrass has been made. Equipment for studying the effect of treatments on the breakdown of the lignin within the cell wall has been obtained and a technician is being trained to prepare and evaluate slides of forage from different treatments.

7. Crop Storage Structures.

1. Silo design criteria. In studies at Beltsville, three silo wall types (1) open, (2) concrete, and (3) metal -- were compared for storage loss of alfalfa silage in a small-scale, 29 day test of wall permeability. Sealed metal and concrete walls gave essentially complete recovery of dry matter regardless of distance behind the wall, while with an open wall, recovery increased with both increasing distance from the wall, up to about 67cm, and with increasing dryness of loaded forage; at each of three dryness levels, recovery at 67cm from the wall was about equal to that in sealed or concrete containers. Combined data for three dryness levels showed a slightly greater recovery from sealed metal than from concrete walls. Protein recovery tended to follow the trends of dry matter recovery except that it increased with increasing dryness with all walls. pH values were slightly lower with sealed walls than with concrete, and minimum in both occurred at .4 dry matter fraction. With open walls, minimum pH occurred at below .3 dry matter fraction.

Work on determination of forage density in normal storage conditions, using a radioisotope, has been completed.

2. Comparison of wilting with other harvest treatments. In studies at Beltsville, alfalfa was ensiled for comparative storage evaluation of 3 harvest treatments: Direct-cut, mechanical dewatering, and wilting, in cooperation with other ARS units and a manufacturer which supplied a prototype dewatering machine. Compared to direct-cut, forage mass per unit of dry matter was reduced 20% by dewatering, and 55% by wilting. Dewatering removed 11% of the crop dry matter, and that forage lost 6% more dry matter in silo juice, while the direct-cut lost 16% in silo juice. Fermentation loss was slightly greater in direct-cut although silage temperatures indicated nearly identical fermentation processes. Feed dry-matter recovery was estimated as: Direct-cut 77%, dewatered 78%, wilted 96%, of the crop. Respective protein recoveries were 73%, 65%, 92%. Dewatering did not significantly improve preservation over direct-cut; wilting was superior to both. Dewatering removed a disproportionate amount of protein. Storage space utilization density was calculated as 6.7 lb/cu.ft. and 10.0 lb/cu.ft. for direct-cut and wilted, and estimated as 7.0 lb/cu.ft. for dewatered silage. In this experiment wilting was by far the best preparation for ensiling.

3. Hay wafer storage. At Beltsville, cylindrical rolled hay wafers were tested for ease of storing and moving, and compared to cubical extruded wafers. Rolled wafers were about as susceptible to molding in drying storage as baled hay, but less so than extruded wafers. Rolled wafers had massing characteristics similar to extruded wafers, but were slightly less coherent and therefore slightly more easily moved. No further work is contemplated.

4. High moisture shelled corn storage. Inactive during reporting year.

5. Grain bin pressures. Inactive during reporting year.

J. Electric Traps for Turf Insects

An experiment at Lafayette, Indiana, was continued for the second year to investigate the use of blacklight traps for controlling sod webworms in lawns. Three 15-watt blacklight omnidirectional traps were operated in lawns having known infestations of sod webworms. These traps were used both to indicate the seasonal abundance and to control the pest. A suction trap (with no attractant) was also operated to sample the diurnal activity of 4 species of crambids. Lawns protected by light traps were essentially free from damage. Trapping with suction and blacklight traps will be continued. Insecticide control studies will be made on heavily infested bluegrass lawns.

K. Radiofrequency Treatment of Grain and Forage Seed

1. Insect Control Studies

Previous research at Lincoln, Nebraska, has shown that all developmental stages of all stored-grain insects studied can be killed by exposure for a few seconds to RF fields of sufficient intensity. Such treatment does not damage the wheat for germination or milling and baking purposes. This electrical treatment would be more expensive than using chemical insecticides for control purposes.

During the past year, a new pulse modulator for modulating a power RF oscillator was completed. This modulator provides pulses of RF energy as short as 50 microseconds to the experimental samples. By applying the RF energy in high-intensity pulses, higher intensity electric fields can be used, which may improve the efficiency of the method for insect control purposes. Even though pulse-modulated treatments were more successful in increasing the mortality of two species of stored-grain insects than unmodulated treatments

at the same energy input, in most of the studies completed so far there was no advantage in pulse modulation. Evaluation of the pulse-modulation equipment is continuing, to provide more conclusive evidence regarding this method for use in stored-grain insect control.

The relative dielectric properties of grain and insects influence the amount of energy each absorbs from the RF electric field. Since the dielectric properties are frequency-dependent, knowledge of these properties over a wide frequency range would be helpful in determining optimum frequency ranges for insect control purposes. During the past year, methods were developed for determining these properties in the 200- to 20,000-Hz range and in the 50- to 250-MHz range. Data are being obtained by these methods and will be used to supplement data already obtained for insects and grain in the 1- to 50-MHz range.

2. Grain and Forage Crop Seed Studies

Previous experiments have shown that RF electrical treatments are effective in reducing the percentage of hard seed and correspondingly increasing normal germination in alfalfa, red clover, ladino clover, and, to a lesser degree, in sweetclover. Quality of RF-treated seed samples continued to hold up as well as untreated seed after 6 years in uncontrolled storage. Similarly, quality of RF-treated seed samples was retained, as well as untreated seed, after 6 years in a controlled storage atmosphere of 40° F. and 50 percent relative humidity. In studies with sweetclover seed, infrared and RF treatments were compared on three different lots of seed, two of which were conditioned to three moisture levels, and one lot to two moisture levels. Only RF treatments produced germination increases in two of the lots, while both infrared and RF treatments improved germination in the other lot. These increases were obtained only with seed dried to about 4 percent moisture and raised the germination from near 50 percent to about 70 percent. One and two additional RF treatments of these samples produced small additional hard-seed reduction.

Germination and early growth of some varieties of seed corn were accelerated by RF treatments. Determinations of early growth were obtained by daily measurements of radicle and plumule growth. Faster early growth in some varieties could not be detected visually but was verified by statistical analysis. Further tests will be conducted to obtain more conclusive evidence of this acceleration for several seed corn varieties. In a very limited study, high-voltage d.c. and a.c. treatments of seed corn did not indicate any accelerated germination or early growth.

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GRAIN AND FORAGE CROPS RESEARCH

of the

UNITED STATES DEPARTMENT OF AGRICULTURE
and related work of the
State Agricultural Experiment Stations

Section B

This progress report is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on USDA and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of USDA and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly USDA publications, Agricultural Research and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D.C.
December 15, 1967

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II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

CORN UTILIZATION - FOOD

Northern Utilization Research and Development Division, ARS

Problem. Utilization of corn in products for human consumption is an outlet of great economic importance. In 1964, U. S. per capita consumption of meal, cereal food, sirup, sugar, and starch obtained from corn totaled 28.3 pounds. If corn used for production of alcoholic beverages is included, this figure would be about 25 percent greater. In processing corn for food and beverage uses, corn oil is obtained as a valuable byproduct. Since 1964, annual production of corn oil has exceeded 400 million pounds. Except for foots and refining losses, all of this oil is consumed in food products, principally margarine and salad and cooking oils.

The need for research is encountered primarily in dry milling of corn where the yield and quality of fractions are important both economically and in terms of consumer acceptance and nutritive value of final products. Improvements are needed in milling techniques, especially for old and artificially dried corn, if optimum results are to be obtained. More information is needed on the composition of corn and corn fractions in order to identify and minimize losses of nutritionally important components that may occur during processing. Such investigations should result in cheaper and more nutritious products and therefore contribute to increased utilization.

In addition, these studies provide a foundation for research on composition, processing, and utilization of new strains of corn now being developed that have significantly higher nutritional value than does ordinary corn. Success in this development could make corn the world's No. 1 food grain. U. S. corn production, which is now 4 billion bushels annually, could be readily expanded to neutralize the present 1-billion-bushel annual world shortage of cereal foods. Since this new corn differs physically from ordinary corn, much effort will be needed to develop suitable milling methods and to provide the knowledge necessary for development of suitable food products to meet dietary needs of world populations.

It has recently been discovered that certain oilseeds and cereal grains, including corn, are subject to infection by molds that can produce toxic products. To provide safe food products, as well as to minimize economic losses, research is needed on the detection of these toxins; on their quantitative analytical determination; and on development of processing techniques for their detoxification or removal from corn.

USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing, long-range program of research involving analytical, organic, and physical chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic, applied, and developmental studies pertinent to utilization of corn in food.

The Federal scientific effort for research on food utilization of corn totals 7.4 scientist man-years. Of this number, 2.2 are devoted to chemical composition and physical properties; 2.6 to color, texture and other quality factors; 1.4 to microbiology and toxicology; and 1.2 to technology--process and product development.

Research at Peoria, Illinois, on chemical composition and physical properties (1.5 scientist man-years) is concerned with lipids and proteins of the corn kernel. A grant has been made to the University of Missouri, Columbia, Missouri, for studies on the interaction of phytin with proteins in processing corn (.7 scientist man-year).

Research at Peoria, Illinois, on color, texture and other quality factors (2.6 scientist man-years) involves study of the reactions of corn sugars with amino compounds.

Research at Peoria, Illinois, on microbiology and toxicology (1.2 scientist man-years) is devoted to studies on the production of mycotoxins by Aspergillus flavus and other molds. The work also includes a survey of the incidence of aflatoxin in commercial samples of various grains. A research contract in effect with the Agricultural Experiment Station, South Dakota State University, Brookings, South Dakota, provides for a survey of various species of Aspergilli to find and identify those producing toxic metabolites. A portion of this effort (.2 scientist man-year) is allocated to research on food uses of corn.

Research conducted at Peoria, Illinois, on technology--process and product development (.9 scientist man-year) comprises investigations on corn dry milling. A grant is in effect at Pennsylvania State University, University Park, Pennsylvania, for basic studies on the mechanical and viscoelastic properties of shelled corn as related to the corn dry-milling process (.3 scientist man-year).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 3.6 scientist man-years is devoted to research on food uses of corn.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Corn proteins, lipids and nonprotein nitrogen components. Compositional studies on corn are relevant both to food and feed utilization. Results are reported under "Corn Utilization - Feed," subheading A.

B. Microbiology and Toxicology

1. Aflatoxin investigations. Studies on toxins produced by molds are relevant both to food and feed utilization of corn. Results are reported under "Corn Utilization - Feed," subheading B-1.

C. Technology--Process and Product Development

1. Corn dry milling. Tests on the response to cold tempering and degermination of corn initially containing 21, 17, and 13 percent moisture indicate that milling of the 13-percent-moisture corn was most affected by the tempering conditions. Increasing temper time gave some improvement in the performance of the 13-percent-moisture corn. The 21-percent-moisture corn gave more flaking grits of lower oil content and more recoverable oil. Milling results with this corn were more consistent than with the lower moisture corns. Additional tests on stress-crack formation during tempering of corn indicate that degree of drying and pretempering influence the extent of stress-crack formation. Work on water flotation of milled corn fractions has shown that good separation of free germ and of high germ fragments from endosperm can be obtained using feed of a particle size range as broad as -4 to +16 U. S. sieve.

2. Mechanical and viscoelastic properties of corn kernels. Under a research grant to Pennsylvania State University, new and better data are being obtained on swelling stresses occurring in the corn kernel during moisture absorption. For a corn initially containing 12 percent moisture, these stresses were of the order of several thousand pounds per square inch. The swelling stresses dropped sharply as the initial equilibrium moisture content increased. Rheological studies showed dependence of deformation characteristics on moisture content of corn kernels. The horny endosperm was the major contributor to the mechanical properties of the corn.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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CORN UTILIZATION - FEED

Northern Utilization Research and Development Division, ARS

Problem. About 75 percent of the U. S. annual production of corn is used as animal feed. Corn is fed to animals in various forms including ear corn, shelled corn, cracked or ground corn and, in certain mixed feeds, corn gluten and other milling fractions. Because of the extremely large volume of this outlet, even small improvements in quality or processing efficiency are economically important to the feed industry and to the farmer.

The components responsible for certain nutritional effects attributed to corn, such as growth stimulation and improved feed utilization efficiency, have not been satisfactorily identified, nor are processing steps available that take these components into account. More information is needed generally on the nutritionally important components of corn and on the changes that occur in them during processing. Besides their activity as Vitamin A precursors, carotenes contribute desirable color to milk and the body fat of cattle. Xanthophyll pigments similarly impart yellow color to egg yolks and to the skin of broilers and fryers. Adequate information on these pigments and on their fate during processing is also needed to insure maintenance and improvement of quality.

Compositional and related processing research is required on several new strains of corn that are expected to become commercially important. These strains include (1) those expected to lead to corn capable of providing a balanced source of amino acids, and (2) those that contain increased amounts of xanthophyll and other carotenoid pigments and therefore would improve the competitive position of U. S. corn in world markets.

Another important direction for research is the fermentative conversion of corn grain and corn sugar to nutritionally important feed additives. The value of corn-based media for production of vitamins, β -carotene, and antibiotics is well known. However, possibilities for additional important developments are virtually unlimited and should be investigated on a continuing basis. Corn steep liquor is frequently used as a supplement in fermentation media and may also be added to feedstuffs. More information is needed on corn steep liquor to identify the factors responsible for its stimulating effects on growth.

It has recently been discovered that certain oilseeds and cereal grains, including corn, are subject to infection by molds that can produce toxic products. To provide safe feed products, as well as to minimize economic losses, research is needed on the detection of these toxins; on their quantitative analytical determination; and on development of processing techniques for their detoxification or removal from corn.

USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing, long-range program of research involving analytical, organic, and physical chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic, applied, and developmental studies pertinent to utilization of corn in feed.

The Federal scientific effort for research on utilization of corn in feeds totals 2.9 scientist man-years, of which 1.5, are devoted to chemical composition and physical properties and 1.4 to microbiology and toxicology.

Research at Peoria, Illinois, on chemical composition and physical properties (1.5 scientist man-years) involves study of lipids and proteins of corn kernels.

Research at Peoria, Illinois, on microbiology and toxicology (1.2 scientist man-years) is concerned with studies on the production of mycotoxins by Aspergillus flavus and related molds. A research contract (.2 scientist man-year*) is in effect with the Agricultural Experiment Station, South Dakota State University, Brookings, South Dakota, for survey of the genus Aspergillus to find and identify species producing toxic metabolites. During the reporting period, research was completed at A. D. Little, Inc., Cambridge, Massachusetts, for studies on stabilization of fermentative β -carotene and with Consolidated Laboratories, Inc., Chicago Heights, Illinois, for research on the use of antimetabolites to facilitate selection of higher yielding strains of microorganisms producing β -carotene.

The Department also sponsors research in this area conducted under grants of PL 480 funds. Research on microbiology and toxicology involves a grant to the Agricultural University, Poznan, Poland, for studies to increase the yield of β -carotene produced by fermentation of cereal grains (4 years, 1966-1970). Effort on this project is prorated among corn, wheat, and sorghum.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 2.6 scientist man-years is devoted to research on industrial and feed uses of corn.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Nonprotein nitrogen components. In research on corn proteins, improved procedures are being developed for isolation of the various classes of corn

*Work covers more than one commodity; only effort allocated to corn is included in total.

proteins by extraction with different solvents. Dialysis of 0.5 M sodium chloride extracts of whole corn against distilled water precipitated globulins and left albumins in aqueous solution. The globulins accounted for 8-12 percent of the corn nitrogen; the albumins represented 7-10 percent, depending on extraction and dialysis conditions. Differences in starch gel electrophoresis patterns were noted between albumins and globulins, although amino acid differences between these fractions were not great. Fractionation of albumins on Sephadex demonstrated that these proteins differ in molecular weight, possibly due to aggregation or disulfide crosslinks. After removal of salt-soluble and 70-percent alcohol-soluble proteins, residual protein was extracted with 0.1 N NaOH to yield a glutelin fraction. This protein was high in molecular weight and did not migrate electrophoretically on starch gel. Further studies on this protein established that glutelin is heterogeneous and may be a mixture of proteins. It contains several components, some of low mobility like that of zein, others of high mobility like that of globulins.

2. Lipids in hybrid corn kernels. Research on corn lipids has resulted in the development of a procedure, based on gas chromatography (GLC), for determining small amounts of triglycerides in corn and corn fractions. Three commercial dent corns were hand-dissected into pericarp plus tip cap (7% of kernel), endosperm (85%), and germ (8%). Crude fat was extracted with n-hexane. Hexane-soluble material in whole corn ranged from 3.7 to 4.5 percent; in pericarp plus tip cap, from 5.1 to 6.5 percent; in endosperm, from 1.9 to 2.0 percent; and in germ, from 27.3 to 32.9 percent. Separation of the lipids by thin-layer chromatography indicated that the various fractions had similar overall class lipid compositions. The largest single fraction was composed of triglycerides. Smaller amounts of hydrocarbons, fatty acids, monoglycerides, diglycerides, sterols, and phospholipids were also present. Triglycerides were separated by GLC on a 3-percent JXR column. The three fractions had similar triglyceride compositions. Average triglyceride composition was C₅₀, 4 percent; C₅₂, 30 percent; C₅₄, 64 percent; and C₅₆, 2 percent. (Designation refers to number of carbon atoms in the fatty acid moiety of the triglyceride.)

B. Microbiology and Toxicology

1. Aflatoxin investigations. The survey for the presence of aflatoxin in oats, corn, and soybeans has now been completed. Two out of 304 oat samples assayed by a modified procedure had 3-6 p.p.b. aflatoxin B₁. Of the 866 samples of soybeans collected, six had 3-6 p.p.b. aflatoxin and one had 7-19 p.p.b. Five positive soybean samples were combined and the presence of aflatoxin confirmed by the duckling test. Aflatoxin was detected at levels of 3-6 p.p.b. in 11 samples and 7-19 p.p.b. in 24 samples of the 1,311 corn samples tested. Positive samples were in all grades of corn except grade 1, but only a total of five samples were positive in grades 2, 3, and 4. The presence of aflatoxin was confirmed biologically in about one-third of the corn samples. One strain of Scopulariopsis brevicaulis

was found to completely and irreversibly remove aflatoxin B₁ from solution. Strains of two Aspergillus species capable of partial removal of aflatoxin were also discovered. Flavobacterium aurantiacum was shown to remove aflatoxin G₁ as well as B₁ from solution. Indeed, cells completely saturated with B₁ readily took up G₁, showing that different metabolic sites are involved. Nocardia species have been shown to actively remove aflatoxins from solution. Engineering studies showed that to maintain good aflatoxin production on solid-rice substrate, no culture beyond third generation from lyophil should be used.

In research under a contract to the University of South Dakota, initial results have revealed a new aflatoxin strain that is nearly as potent as NU's best selection. Survey of 107 Aspergillus strains has picked up a strain of A. parasiticus (NRRL 465) which, when grown on soybeans, is the strongest aflatoxin-producing strain yet encountered. It forms many more times the aflatoxin produced by A. flavus (NRRL 2999) under similar conditions. The A. candidus and A. versicolor groups are Aspergilli fairly regularly encountered in cereals. None of the later strains tested showed toxicity. A strain of Aspergillus clavatus was found to cause reduced growth in chick-feeding tests; however, this strain does not produce aflatoxin. Two or three mildly toxic strains were encountered in A. sydowi and A. versicolor groups, including one strain recently isolated from wheat flour. Microscopic examination of livers of the chicks fed material from these cultures showed liver changes.

2. Beta-carotene synthesis. Under a PL 480 grant to the Agricultural University, Poznan, Poland, production of beta-carotene by mated cultures of Blakeslea trispora is being studied. Particular emphasis is being placed on the factors in spent mycelium, from a previous fermentation, that greatly enhance carotene yields. Initial work was concerned with replacing medium components previously found to be optimal for production with substances available in Poland. Pharmamedia was replaced by brewers yeast and ground whole soy; Deobase by Polish-made kerosene "KB"; the detergent Triton X-100 by "Alfenol"; citrus molasses by beta-ionone. Yields almost equivalent to those obtained with the original medium were attained (100 mg./100 ml. medium). Spent mycelium added in place of citrus molasses or beta-ionone stimulated carotene synthesis but not to the same extent as did the replaced substances.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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CORN UTILIZATION - INDUSTRIAL PRODUCTS
Northern Utilization Research and Development Division, ARS

Problem. About 3 billion pounds of cereal starches and flours are used annually in the U. S. for industrial purposes. Corn is the source of most of these products. Industrial outlets for starches and flours are, however, constantly threatened by synthetic products derived from nonagricultural sources. Maintenance of the present and future competitive position of corn starch and flour in industrial markets requires a continuing program of basic and applied research.

The most promising outlets for new and improved industrial products derived from corn include the paper industry, industrial chemicals, adhesives, protective coatings, plastics, elastomers, and thickening agents. The greatest opportunity exists in the manufacture of paper and paperboard products, the U. S. production of which is over 40 million tons per year and growing at a considerably faster rate than is population. Not only the total volume of starch consumed in the paper industry but also the average amount used per ton of paper product has increased very substantially since 1950. This favorable picture stems from research conducted in the past. To maintain or, more desirably, to increase the utilization of corn starch and flour in competition with synthetics, new concepts must be evolved that relate chemical modification of starch with specific properties imparted to paper products. Technology must be developed to establish optimum procedures for industrial use of promising products currently under study such as starch xanthates, starch graft copolymers, cyanoethylated and sulfated starches, and the new starch from high-amylose corn.

Industrial chemicals provide a multibillion-pound annual market in which starch-derived products should share to an increasing extent. At 5 to 6 cents per pound, corn starch is an attractive raw material for the manufacture of industrial chemicals. When fermentative, rather than conventional chemical, conversion is applicable, even cheaper sources of starch such as flour and ground whole grain can be used as the raw material. Over a billion pounds of corn sugar is used annually in the manufacture of such well-known industrial chemicals as sorbitol, mannitol, citric and gluconic acids, and methyl glucoside. Promising leads requiring research to insure successful future developments include nitrogen, sulfur, and unsaturated derivatives of starch, vinyl glucosides, industrial enzymes, and enzymatic starch conversion products such as oligosaccharides, polyols, and glucosides.

Adhesives represent a field long dominated by starch, which accounts for nearly half of the annual 2-billion-pound market for these products. However, competition by synthetic resins is especially vigorous and effective because of the specialized properties required to achieve increased production of products like corrugated container board on automatic

machinery. The overall growth rate of adhesive consumption is almost 7 percent per year. Since starch is usually cheaper than synthetic adhesive resins, prospects are good for meeting the competition through research designed to improve viscosity properties, bond strength, tack, and drying time of starch-derived adhesives.

The remaining outlets--coatings, plastics, elastomers, and thickeners--represent a multibillion-pound market in which starch-derived products having suitable properties should find ready acceptance. Microbial polysaccharide gums, starch graft copolymers, and urethane foams from starch-derived polyols typify the products that result from research on corn starch and flour.

Research oriented specifically toward particular industrial applications of final products must be founded on a vigorous and wide-ranging program of basic and exploratory investigations. Such studies lead to the discovery of new concepts, principles, and reactions that are the source of new processes and products for future development.

USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing, long-range program of research involving analytical, organic, and physical chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic, applied, and developmental studies on the composition of corn, on characterization and properties of the components, and on their chemical and microbiological conversion to useful industrial products.

The Federal scientific effort for research on industrial utilization of corn totals 59.3 scientist man-years. Of this number, 10.0 are devoted to chemical composition, physical properties and structure; 18.2 to chemical and physical investigations to improve products; 20.7 to microbiology and fermentation; and 10.4 to technology--process and product development.

Research at Peoria, Illinois, on chemical composition, physical properties and structure (8.4 scientist man-years) involves study of starch, amylose, amylopectin, proteins, and lipids of corn. A portion of the work is related to problems pertinent to high-amylose corn. During the year, studies on the rheological properties of starch were initiated. Grants (1.6 scientist man-years) are in effect with Iowa State University, Ames, Iowa, for basic research* on heat, mass, and momentum transport of cereal starches and flours; Purdue Research Foundation, Lafayette, Indiana, for research* on the effects of disulfide bond cleavage on the structure of corn and wheat endosperm proteins; Arizona State University, Tempe,

*Work covers more than one commodity; only effort allocated to corn is included in total.

Arizona, for basic investigations of the helical structure of amylose; and the State University of New York, Syracuse, New York, for investigations of starch fine structure. Grant research was completed by the Nebraska Agricultural Experiment Station, University of Nebraska, Lincoln, Nebraska, for basic studies on variations in starch granules of genetically different corn samples and by Princeton University, Princeton, New Jersey, for basic research on the relationship of viscoelastic properties of amylose film to structure and function of plasticizers.

Research at Peoria, Illinois, on chemical and physical investigations to improve products (12.2 scientist man-years) is directed to wide-ranging study of the chemical reactions of starch with the objective of discovering new chemical products and processes having potential for industrial use. During the year, studies on starch-based plastifoams were completed and research on related noncellular plastics was initiated. Research contracts (2.5 scientist man-years*) are in effect with the Arizona Agricultural Experiment Station, University of Arizona, Tucson, Arizona, for basic studies on the reaction of acetylene with methyl glucoside; with the University of Akron, Akron, Ohio, for evaluation of starch and starch derivatives as reinforcing agents for natural and synthetic rubber; with Southern Illinois University, Carbondale, Illinois, for investigations on synthesis of maltooligosaccharides; with the Institute of Paper Chemistry, Appleton, Wisconsin, for investigation of physical chemical factors affecting retention and effectiveness of starch xanthates and xanthides in paper; and with General Mills, Central Research Laboratories, Minneapolis, Minnesota, for studies on the development of cereal proteins having utility as flotation and flocculating agents. Contract research was completed by The Johns Hopkins University, Baltimore, Maryland, for basic research on the reactions of starch in fluid dynamic media, and with Stanford Research Institute, Menlo Park, California, for research on graft copolymers of cereal starches with vinyl-type monomers. Grants (3.5 scientist man-years*) are in effect at Ohio State University Research Foundation, Columbus, Ohio, for basic research on the reaction of vinyl ethers with carbohydrates; at Ohio State University, Columbus, Ohio, for basic investigations of unsaturated and sulfur-containing carbohydrates and of the amination of starch; at Purdue Research Foundation, Lafayette, Indiana, for studies on sugars containing carbon-bound nitrogen, phosphorus and sulfur; at the University of Pittsburgh, Pittsburgh, Pennsylvania, for studies on dielectric activation of starch; at the University of Arizona, Tucson, Arizona, for basic research on the reaction of starch with diepoxides; and at Southern Illinois University, Carbondale, Illinois, for studies on the alcoholysis of carbohydrate esters.

Research on microbiology and fermentation conducted at Peoria, Illinois, (16.4 scientist man-years) includes studies on the use of microorganisms

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to convert cereal-based media to industrially useful products such as chemicals, enzymes, polymers, and biological insecticides. A large collection of pure cultures of industrially and agriculturally important microorganisms is maintained. The Pioneering Laboratory for Microbiological Chemistry conducts research on microbiological reactions and products. Investigations on biological insecticides for Japanese beetle and on other insect control agents is cooperative with Entomology Research Division and Plant Pest Control Division. Research on plant antibiotics involves cooperation with Crops Research Division. Research contracts (1.2 scientist man-years*) are in effect at Michigan State University, East Lansing, Michigan, for basic research on enzyme activity in sporulation; at the University of Minnesota, St. Paul, Minnesota, for fundamental studies on the transfer of genetic determinants of sporulation from one microorganism to another; at Baylor University, Houston, Texas, for investigation* of morphological changes involved in sporulation; at the American Type Culture Collection, Rockville, Maryland, for studies on preservation of certain microorganisms for which lyophilization is ineffective; and at Michigan State University, East Lansing, Michigan, for investigation of the biochemical properties of variant cultures of Bacillus popilliae. Contract research at the Kansas State University, Manhattan, Kansas, for investigation of stabilization of vegetative cells of the pathogenic organisms has been completed. Grants (3.1 scientist man-years*) are in effect with Cornell University, Ithaca, New York, for fundamental studies on biphasic fermentation; Kansas State University, Manhattan, Kansas, for investigations on separation of enzymes and proteins by disc electrophoresis; Iowa State University, Ames, Iowa, for investigation* of bacterial amylases and their action patterns; the University of Wisconsin, Madison, Wisconsin, for studies on the fine structure of polysaccharide B-1973; the University of Arkansas, Fayetteville, Arkansas, for investigation of the mechanism of enzymatic hydrolysis of starch; the University of Nebraska, Lincoln, Nebraska, for structural studies of fungal glucosylhydrolases; Baylor University, Houston, Texas, for cytology of ascospore formation in yeasts; the University of Minnesota, Minneapolis, Minnesota, for studies of cellular differentiation and physiology of selected molds; East Texas State University, Commerce, Texas, for determinations of branching in polysaccharides; and Indiana State University, Terre Haute, Indiana, for surveys of gum-producing microorganisms. During the year, grant research was completed by Nebraska Agricultural Experiment Station, University of Nebraska, Lincoln, Nebraska, for investigations on the nature of amylase enzymes.

Research conducted at Peoria, Illinois, on technology--process and product development (8.1 scientist man-years) is concerned with detailed study and evaluation of starch derivatives having definite potential for industrial utilization and of processes for making them. Research contracts (2.3 scientist man-years*) are in effect with Stanford Research Institute,

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Menlo Park, California, for process development of selected starch graft copolymers; with Western Michigan University, Kalamazoo, Michigan, for evaluation of modified cyanoethylated starches for applications in paper; with Battelle Memorial Institute, Columbus, Ohio, for studies on starch derivatives for use as colloids in water-emulsion paints; and with Archer Daniels Midland Company, Minneapolis, Minnesota, for investigations on the use of starch glycosides in coatings and plastics. During the year, contract research on starch and other cereal grain xanthides was completed by Battelle Memorial Institute, Columbus, Ohio.

The Department also sponsors research on cereal starches conducted by foreign institutions under grants of PL 480 funds.^{*} Research on chemical composition, physical properties and structure involves grants to the University of London, London, England, for research on debranching enzymes and their use in studying the fine structure of starch components (5 years, 1963-1968); to the University of Osaka Prefecture, Sakai, Japan, for development of an analytical method for carbonyl groups in carbohydrates (4 years, 1964-1968). During the year, research on glucopyranose rings in starches and dextrans was completed at the "Giuliana Ronzoni" Scientific Institute for Chemistry and Biochemistry, Milan, Italy.

Research on chemical and physical investigations to improve products involves grants to Hebrew University, Jerusalem, Israel, for studies on starch vinyl and epoxide graft copolymers (4 years, 1963-1967); Ahmedabad Textile Industry's Research Association, Ahmedabad, India, for research on starch-gum copolymers prepared by codextrinization (5 years, 1963-1968), and for studies on preparation and characterization of hydroxyethyl ethers of cereal starches (5 years, 1965-1970); Slovenian Academy of Sciences and Arts, Ljubljana, Yugoslavia, for studies on modification of starch by moisture and temperature treatments (5 years, 1964-1969); Plastics Research Institute TNO, Delft, The Netherlands, for research on preparation of metal alkoxides of starch for use as intermediates in synthesis (5 years, 1964-1969); University of Edinburgh, Edinburgh, Scotland, for studies on the mechanism and structural changes involved in thermal, acid, and alkaline degradation of starches (5 years, 1964-1969); Institute for Fibres and Forest Products Research, Jerusalem, Israel, for studies on the mechanism and products of mild oxidation of starch (5 years, 1963-1968); and to the University of Graz, Graz, Austria, for rheological studies on aqueous dispersions of modified cereal starches and paper coating formulations containing starch-based adhesives (3 years, 1966-1969). During the year, research was completed on phosphorus- and sulfur-containing cationic starches at the National Institute of Technology, Rio de Janeiro, Brazil.

Research on microbiology and fermentation involves grants to the University of Allahabad, Allahabad, India, for studies on survival of lyophilized

^{*}Effort prorated among corn, wheat, and grain sorghum.

microorganisms (5 years, 1962-1967); Central Drug Research Institute, Lucknow, India, for studies on aerobic actinomycetes in India to find new accessions for the ARS Culture Collection (5 years, 1965-1970); the University of Liege, Liege, Belgium, for research to find lytic enzymes of microbial origin (5 years, 1964-1969); the University of Lodz, Lodz, Poland, for research on the fermentative production of itatartaric acid (5 years, 1963-1968); University of Tokyo, Tokyo, Japan, for research on the fermentative production of D-tartaric acid (5 years, 1964-1969) and of mevalonic acid (3 years, 1965-1968); the National Sugar Institute, Kanpur, India, for research on isolation of natural polysaccharide gums (3 years, 1965-1968); and the National Institute of Agronomic Investigations, Madrid, Spain, for study and collection of aerobic species of actinomycetes (4 years, 1965-1969). During the year, research was completed on collection of new *Mucorales* species at the University of Allahabad, Allahabad, India; on investigations of sugar phosphate derivatives in molds at the University of Newcastle upon Tyne (formerly University of Durham), Newcastle upon Tyne, England; and on studies on the preparation and characterization of dextran derivatives at the University of Rome, Rome, Italy.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 2.6 scientist man-years is devoted to research on industrial and feed uses of corn.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition, Physical Properties and Structure

1. High-amylose (HA) corn development. Studies on structural and chemical differences in corn genotypes show that the basis for high lysine content of certain opaque and floury mutants is greatly reduced deposition of low nutritional quality zein protein and concomitant increase in deposition of glutenin and globulin, both of which are relatively high in lysine and other basic amino acids. A new type of zein need not be postulated to explain the altered protein composition. During the past year, 14,900 amylose analyses have been completed for the cooperating plant breeders working on the development of high-amylose corn. Of these samples, 204 assayed 85 percent apparent amylose or higher. The highest sample assayed at 87.9 percent apparent amylose. Work on improving and simplifying the amylose analysis continues with studies on the determination of amylose in dimethyl sulfoxide extracts of high-amylose corn. In analyzing the whole corn kernel for amylose rather than only the endosperm protein, it was found that the oil from the germ appears to have no effect on the amylose determination in DMSO extraction method. Most recent evaluation of error of DMSO method shows a standard deviation of ± 1.2 percent amylose for corn with about 80 percent amylose.

2. Chemical studies on corn components. A general method for isolation of minimally degraded corn starch was developed. It involves low temperature

dispersion with either concentrated salt solutions or 90 percent DMSO and the use of enzymes to remove bound protein. This procedure consistently yields amylopectin having a very high molecular weight (\bar{M}_w , 6.6×10^8). In aqueous solution, amylopectin obtained from 70 percent high-amylose (HA) corn displayed retrogradation, whereas comparable fractions from dent or waxy corn starch did not; the amylose fraction from HA corn also differed in retrograding more easily than amylose from dent corn. Stable amylose fractions of dent corn were prepared in concentrated salt solutions. It was found possible to proceed from a DMSO dispersed sample to both the BuOH-amylose complex and a 4 M guanidinium hydrochloride (GHC1) amylose solution and from the BuOH complex to the 4 M GHC1 solution. No residual DMSO or GHC1 was found with the amylose after conversion to the butanol complex and precipitation in EtOH-MeOH solution.

Grant research at the Arizona State University on reactions of helical amylose with small molecules shows that at pressures above 525 mm., HCl degrades amylose, whereas below this pressure the "V" crystal lattice is unaffected. Crystallographic and chemical considerations of the crystal structure of the KBr-amylose addition compound indicates that the correct space group is $P4_32_1$. The three dimensional Patterson map revealed peaks which were assigned as Br-Br and KBr interactions for Br^- situated at (.20, .20, 0) and K^+ at (.54, .54, 0).

Studies under a grant to Purdue University on disulfide bond cleavage in wheat and corn proteins has revealed that the increased lysine in opaque-2 corn is due to a high content of globulin and glutelin but not to a change in zein composition. Work continues under this grant on the development of extraction procedures for recovering the various proteins from opaque-2 and dent corns.

A micromethod has been developed at the University of London, London, England, under a PL 480 grant for the determination of the chain length of glycogen and amylopectin which requires the simultaneous and complete degradation of the polysaccharide with β -amylose and pullulanase to maltose and glucose. The specific determination of glucose permits the calculation of a chain length. The reliability of the method has been confirmed with glycogen and amylopectin samples whose chain length had been determined by periodate oxidation. Considerable effort has been expended to verify the enzymatic purity of the β -amylose and pullulanase used. The β -amylose obtained commercially contained variable amounts of a maltose which could be partially removed by gel filtration on Sephadex G-100 or suppressed by erythritol. The pullulanase, an acetone powder of the extracellular medium of a culture of Aerobacter aerogenes grown on maltose is enzymatically pure. However, gel filtration on G-200 Sephadex has removed inactive contaminants, purified the enzyme 16-fold, revealed the presence of two active molecular sizes, 100,000 and 50,000, which are interconvertible. Further developments in this project will be limited by its early termination, September 30, 1967.

3. Physical studies on corn components. In NMR studies on grain constituents and grain-derived products, properties of the fungal metabolite, ramulosin, were investigated using IR and ultracentrifugation in addition to NMR. Comparison of ramulosin with several other much-studied β -diketones suggests that one of the stable forms might be an enol-dimer. The integrated optical density at $1,600\text{ cm}^{-1}$ is linearly related to the calculated monomer concentration obtained from NMR data. Ring vibrations of the dimer would be very weak in the infrared since they are symmetrical. Therefore, raman spectra have been obtained on two concentrations of ramulosin in CHCl_3 . After these data are analyzed, the results will be compared with the calculated dimer concentration. Utility of NMR techniques in structural and mechanism problems should be increased by computer programs currently being devised to assist in the analysis of complicated spin systems.

A complete crystallographic characterization was successfully obtained by X-ray analysis of oriented films of amylose made from the amylose-DMSO complex. The molecular configuration is helical, with six glucose units per turn of the helix and a repeat distance of 8.1 \AA along the c axis. The helices are packed in a square array with $a_0 = b_0 = 9.1\text{ \AA}$. Symmetry is orthorhombic. This structure has been named " V_{DMSO} ." Optical rotatory dispersion studies on amylose films show that there is a direct correlation between structure of amylose in the solid state and its conformation in solution. The specific rotation of amylose V_{DMSO} , amorphous, and alkali films is the same as that of amylose in corresponding solutions of DMSO, $0.5M$ KCl and alkali. Tests at 16 and 50 percent relative humidity showed that folding endurance of oriented and amorphous films was not changed; however, oriented films had 25 percent greater tensile strength. Photomicrographs and X-ray patterns showed that when films are cast from aqueous dispersions, particles having the "B" structure stick together to form a highly strained film that is brittle at low R.H. When films are cast from DMSO dispersions, crystallization occurs after the film has formed from amorphous amylose.

Under a grant at Princeton University, now completed, modulus-temperature curves were obtained for amylose plasticized with DMSO. The results of these measurements, together with X-ray diagrams, showed that amylose exists as a semi-crystalline polymer in films containing 40 percent or less DMSO. As DMSO increases, crystallinity is lost. The glassy modulus was not affected by incorporation of DMSO, but the rubbery modulus and glass transition temperature (T_g) were depressed.

At Iowa State University, studies under a research grant showed that stirring wheat flour very slowly made air fluidization of the flour possible without the necessity of adding fluidizing agents. Stirring had about the same effect on the behavior of the bed as fluidizing agents except that stirred bed expansion and entrainment are much smaller. Studies on sorption and desorption of water by thin layers of starch showed that desorption took place more slowly than sorption. Sorption rates were observed to be so rapid that 90 percent of equilibrium sorption was reached in 15 seconds.

Rate of sorption of water by starch is affected by the drying conditions and relative humidity of the air. The diffusivity of water vapor is ca. 1×10^{-8} sq. cm./sec. Thermal conductivity of starch is close to that of carbon tetrachloride.

Research conducted under a PL 480 grant at the "Giuliana Ronzoni" Scientific Institute of Chemistry and Biochemistry, Milan, Italy, extends and augments NU research on amylose and model compounds in aqueous solution, with emphasis on conformation in DMSO (dimethyl sulfoxide) solution. Infrared and nuclear magnetic resonance studies have shown amylose and model compounds including cyclodextrins dissolved in DMSO to have the C1 chair form in solution. Evidence is presented showing the probability of O_2H-O_3H' hydrogen bonding in DMSO and the stabilization of the helix which this would bring about. A most thorough characterization of cyclodextrins and oligosaccharides, as well as amylose, by IR and NMR has been made including measurements of dichroism in the IR. Three analytical methods were developed in the course of this work: (a) determination of the anomeric configuration and percent anomers of reducing pyranoid sugars; and NMR method based on the magnitude of the H_1H_2 coupling as an indication of the dihedral angle; (b) determination of the composition of mixtures of α - and β -cyclodextrins; an NMR method based on differences in the spectra in the 4.0-4.7 τ region; and (c) determination of the degree of substitution of partially O-methylated amylose and dextrans; an NMR method relating the area of the OH signal to the C_1H signal. This research was completed during the year.

Studies at the University of Osaka Prefecture, Sakai, Japan, showed that a reaction of glucose with o-phenylenediamine gave a quinoxaline derivative that can be determined polarographically. Reaction conditions are being sought for making this method of derivatization applicable to the determination of carbonyl groups in starch and its reaction products. This work is being conducted under a PL 480 grant.

B. Chemical and Physical Investigations to Improve Products

1. Reactions of maltose and glucose. A simplified method has been developed for preparation of anhydrous, non-hygroscopic, high-melting, heat-stable, crystalline maltose. The method involves merely heating the common β -maltose hydrate in a little solvent at 90-100° C. Fifteen different organic solvents and water were used to produce 80-99 percent yields of maltose that contained from 70-83 percent of the more heat-stable α -anomer. Subsequent extractions increased the α -content to 95 percent and gave a new form of maltose with a melting point of 191-193° C. This work suggests the possibility of producing anhydrous α -maltose industrially by heating, seeding, and drying a concentrated maltose sirup. Studies of complexing maltose with ureas showed that an equilibrium exists between complexed and uncomplexed carbohydrate. For several ureas tested, the extent of complexing with maltose decreased in order: urea, monomethyl urea, N,N'-dimethyl urea, cyclohexyl urea. L-arabinose, D-galactose, D-mannose, D-fructose, and methyl α - and β -D-glucopyranosides did not form

an isolable complex. Further studies have shown the importance of the solvent used in forming and precipitating the complex. Both 1:1 and 2:1 maltose-urea complexes have been isolated by use of different combinations of solvent. Structure of a new maltose heptaacetate has been determined to be 1,2,6,2',3',4',6'-hepta-O-acetyl β -D-maltose; the hydroxyl group at C3 was not acetylated by pyridinium acetyl chloride in toluene.

2. New derivatives of starch and related carbohydrates. Experiments on halogen derivatives of carbohydrates have shown that the acid-catalyzed condensation of chloroacetaldehyde diethyl acetal and D-galactitol, D-mannitol, or D-glucitol yields in each case a bis(chloroethylidene) derivative. Characterization of the galactitol derivative showed that the two chloroethylidene groups were linked to the carbohydrate at the 1,3 and at the 4,6 positions, respectively. These derivatives displayed unusual stability to acid conditions. The acid-catalyzed condensation of bromoacetaldehyde with D-mannitol gave a crystalline product which was separated by extensive purification into a high and a low melting isomer of di-O-bromoethylidene-O-mannitol. Although the infrared spectra of these isomers were nearly identical, the di-O-p-tolylsulfonyl and di-O-acetyl derivatives of the isomers were different, indicating that the isomers are not different crystalline modifications of the same compound. This particular reaction does not follow the Hann and Hudson rules for predicting structure of the polyolacetal derivatives.

In the contract research at Southern Illinois University, the following steps in synthesis of C4-modified maltooligosaccharides were accomplished: (1) Amylose was successfully blocked with O-benzyl ether groups. 2,3,6-Tri-O-benzyl amylose was prepared for the first time, using benzyl chloride and sodium hydroxide in dimethyl sulfoxide. (2) The perbenzylated amylose was methanolized with hydrogen chloride catalyst to methyl terminal-4-hydroxyl-perbenzylated maltooligosaccharides (I) which were separable at this stage by thin-layer chromatography. (3) The products (I) were methylated to form perbenzylated methyl terminal-4-O-methyl maltooligosaccharides (II). (4) The products (II) collectively were debenzylated either by bromination of the benzyl methylene group, followed by hydrolysis (a new method) or by hydrogenation with Raney nickel at 50° C., 60 p.s.i. Both methods fail with products of D.P. greater than 4 or 5; however, hydrogenolysis was more effective than bromination and hydrolysis at D.P. 5. (5) The deblocked methyl terminal-4-O-methyl-maltooligosaccharides of D.P. 1-4 were separated by both carbon and Sephadex column chromatography.

Studies on unsaturated and sulfur-containing carbohydrates under a grant to Ohio State University have provided high-yielding routes for converting sugars to dimethylthiocarbamate esters, to a new class of furan derivatives, to novel ketoaldehydes, and to derivatives containing 2,3-alkene bonds. Major effort on the reactions of unsaturated sugars under hydrolytic conditions has shown a stepwise series of conversions that are believed to be general for sugars having 1,2- or 2,3-olefinic unsaturation. Structures

proposed in the old literature for a number of transformation products of unsaturated sugars are shown to be incorrect.

Under grant research conducted at Purdue University, nitrogen and sulfur were successfully introduced into the 5 position of sugars by reacting the 3,5-anhydro derivatives of D-glucose and D-xylose with azido, hydrazino, benzylthio, and thiosulfate ions. Phosphorus was introduced at the 1 position via reaction of tetra-O-acetyl-D-glucosyl bromide with sodium diethyl phosphite, but attempts to introduce phosphorus on D-glucose C-5 or C-6 carbon atoms by reacting sodium dibenzyl phosphite or tribenzyl phosphite with 5-O-tosyl or 5-deoxy-5-halogeno derivatives were not successful.

At the University of Arizona, a grant is currently in effect for studies on diepoxide-starch reactions. Suitable procedures for preparation of diepoxides are currently being investigated. Reaction conditions so far explored gave low yields.

At the Plastics Research Institute TNO, Delft, The Netherlands, starch with a high specific surface area (about 100 m²/g) prepared by methods developed previously in this study was converted to sodium starchates by treatment with sodium methylate in a tetrahydrofuran-methanol mixture (80:20 parts by weight). Under the best conditions the degree of substitution (D.S.) as determined by direct analysis for sodium was only 1.5 out of a possible 3.0. Conversion to the methyl ethers by treatment with methyl iodide under nitrogen gave products with methoxyl D.S. equal to about one-half the original sodium D.S. Apparently about one-half the sodium in the sodium starchates is present as sodium methylate. Considerably lower methoxyl values are obtained if the methylation is done in air instead of under nitrogen. This is apparently due to oxidative reactions of an undetermined nature. Starches with high specific surface areas also were found to adsorb up to 70-80 percent of their weight of butanone, acetonitrile, and tetrahydrofuran. However, rates of adsorption were slower than on charcoal. This work is being conducted under a PL 480 grant.

3. Graft copolymers. In alkaline hydrolysis of a starch-polyacrylonitrile graft copolymer (1:2) (1 graft per 892 AGU; M.W. of grafted polyacrylonitrile (PAN) chains, 286,000) degree of conversion of the intermediate amide to acid was found critical in achieving maximum viscosity. Viscosities of 0.5 percent dispersions of hydrolyzed copolymers were about 10 times greater than most viscous commercial gums, including B-1459. Viscosities in the presence of KCl equalled or exceeded those of CMC and at the 1 percent level were comparable to those of microbial polysaccharide B-1459. Alkaline hydrolysis of a 1:1 copolymer (1 graft per 4,623 AGU; M.W. of grafted PAN, 800,000) gave products characterized by high viscosities, 15,000-26,500 cps. at 1 percent level. In the ceric-ion-initiated grafting of PAN, the number of grafted chains was increased and their average molecular weight reduced by employing aqueous organic solvent systems instead

of water alone. High dilution of starch and acrylonitrile in water also yielded copolymers with more grafted chains and lowered the molecular weight of grafted PAN. The products prepared under high dilution conditions contained about 40 percent PAN, and amount of ungrafted PAN was negligible. There was no correlation between granule size and grafting frequency, indicating that the starch granules were grafted throughout rather than surface grafted.

In research under a PL 480 grant to the Hebrew University, Jerusalem, Israel, ethylene oxide and propylene oxide were grafted by anionic means to cereal starches dissolved in dimethylsulfoxide. Depending on the polyalkylene oxide content of the graft copolymers, graft chain length varied from about 2 to 8 monomer units, and graft chain frequency ranged up to about 1 graft chain per anhydroglucose unit. Copolymers containing from 30 to 35 weight percent grafted polyalkylene oxide were the easiest to purify and were obtained in highest yields (up to 85 weight percent based on the combined weight of starting materials). These products are soluble in water and in methanol but insoluble in acetone. Aqueous dispersions of the products are viscous and sticky. Lauryl methacrylate, 4-vinyl pyridine, methacrylonitrile, and methyl methacrylate were also anionically graft copolymerized with starch. In general, yields were poor and only the 4-vinyl pyridine graft copolymers of starch were water soluble. All other products were insoluble in water and common organic solvents.

4. Thermal reactions of starch. In studies of starch reactions in a dielectric field, conducted under a grant to the University of Pittsburgh, initial experiments with a new 5 Kw. R.F. generator showed a 3.5 percent disappearance of granular starch in 5 minutes. Then, only levoglucosan was detected by GLC in the condensate. Practically all the starch was pyrolyzed in 25 minutes; then four other compounds were detected. Two of these compounds, obtained in yields equal to that of levoglucosan, were tentatively identified as 1,6-anhydro- β -D-glucofuranose and 1,6-anhydro- β -D-galactopyranose. These results were obtained in a simple batch-type reactor. Three types of continuous reactors have been designed and two are being constructed.

At the University of Edinburgh, Edinburgh, Scotland, work on thermal degradation of starches was continued to include a variety of granular cereal starches. Evaluation of the major gaseous products, CO_2 , CO, and H_2O , under conditions of high vacuum and temperature ranges of 150-350° C. indicates that apparent differences between starches were small. The thermal stability of amylomaize starch is greatly affected by small amounts of simple inorganic salts. A method of fractionating amylomaize starch was developed which includes treatment of the defatted granules with DMSO and formation and separation of various fractions with butanol and iodine as the respective complexes of these materials. Acid hydrolysis of starch fractions and enzymatic methods of characterizing chain length and amounts of branching

are being studied. A method for determining number average molecular of linear oligomers has been developed using enzyme methods. This work is being conducted under a PL 480 grant.

5. Chemical products from starch. Hypochlorite-oxidized cyanoethylated corn starch (D.S. 0.1) has promising properties for use as a binder for pigment coating of paper. Alkali-hydrolyzed cyanoethylated starch was not satisfactory for this purpose. Preliminary experiments indicated that cationic compounds containing C_{12} - C_{18} fatty radicals are strongly adsorbed by starch and cellulose. Over 50 cationic additives admixed but not directly reacted with starch were screened for cationic efficiency. Imidazoline and trimethyl ammonium chloride derivatives selected from this group for handsheet evaluation required twice the concentration of additive to equal tensile and burst strengths obtained with commercial cationic starches. However, on a cost basis, higher concentrations of cationic additives were still competitive. Clay filler retentions (% ash) on handsheets remained inferior to commercial starch products even at the higher concentrations. Details are being developed for the low-cost synthesis of a cationic reagent, 2,3-epoxy-propyltrimethyl ammonium chloride, for use in reactions with starch.

Water-soluble forms of dialdehyde starch (DAS) are now commercially available. Two of these have been found suitable for use in DAS-protein plywood glue. Collaborative quality testing of DAS-protein glue bond in NU-prepared southern pine plywood panels give scores for the panels ranging from 98 to 100 percent, far surpassing minimum glueline requirements for interior-grade southern pine plywood. Studies on relationship of moisture content of southern pine veneers to satisfactory glue bond of plywood have set guidelines for conducting the American Plywood Association's "A" test for evaluating DAS-protein glue under actual plywood mill operation.

Zinc starch xanthate (ZSX), used as a filler in TiO_2 -pigmented natural rubber compositions, resulted in products equivalent to conventional white sidewalls prepared from natural rubber. When used in similar styrene-butadiene rubber (SBR) composition, ZSX gave products equal to SBR reinforced with carbon black and much stronger than SBR containing conventional white fillers. ZSX was found to facilitate incorporation of lignin into SBR. Products had properties superior to those achievable with either filler alone and, for certain formulations, superior to those for SBR reinforced with carbon black. Resorcinol-formaldehyde crosslinked starch incorporated into SBR was found to be highly reinforcing. Resorcinol-resin crosslinked starch gave rubber with higher maximum tensile strength than could be obtained with ZSX. At high loading, the resin crosslinked starch dispersed in SBR better than ZSX and gave smooth, glossy, very strong rubbers, but they were slow in curing. Reaction between starch xanthate and polyacrolein bisulfite in aqueous medium results in a product best characterized as being a thionocarbonate. Preliminary tests show that about 33 percent is the best attained retention of the product thionocarbonate in paper pulp mats.

Under contract research at the Institute of Paper Chemistry, studies on retention of starch xanthates and xanthides by wood pulp show that adsorption of xanthate prior to oxidation to xanthide is not a determining factor in xanthide retention. Performance of starch xanthides formed in situ has been shown to be dependent upon both ionic strength of oxidation system and fiber concentration. However, changes in crosslinking conditions affect these conclusions so that further studies will be directed toward adsorption of starch xanthides.

At the Ahmedabad Textile Industry's Research Association, Ahmedabad, India, commercial hydroxyethyl corn starch of D.S. (degree of substitution) of approximately 0.1 was oxidized with sodium periodate, and the dialdehyde obtained reduced with sodium borohydride. Hydrolysis of the polyalcohol and fractionation yielded erythritol, 2-Q-hydroxy-D-glucose, 3-Q-hydroxy-D-glucose (trace), and hydroxyethylerythritol. Glucosylerythritol and 2-Q-hydroxyethyl glucosylerythritol were also obtained. The results indicate that the commercial product was etherified at the C-2 position of the glucose unit to the extent of about 84 percent of the hydroxyethylation. Most of the remaining ether groups were located at the C-6 position with negligible reaction at C-3.

In other research at this institution, dextrin prepared by heating corn starch and gum karaya in the proportion of 6:4 with 0.07 percent HCl at 153° C. for 8 hours, was exhaustively fractionated with Cetavlon and with barium hydroxide. The results indicate that under the above conditions of dextrinization, copolymerization of the starch and karaya fragments does not take place. Corn starch has also been dextrinized in varying proportions with guar gum, glycine, and gluten at 213° C. without catalyst and at 153° C. in the presence of 0.08 percent HCl. It has been found that glycine, gluten, and guar gum reduce the dextrinization of starch-guar gum mixtures under acid conditions. These investigations were conducted under PL 480 grants.

During the year, studies were completed under a PL 480 grant at the National Institute of Technology, Rio de Janeiro, Brazil. In the final phases of this work, xanthates, thioglycolates, and thiodiglycolates of starch were prepared in efforts to synthesize tertiary sulfonium derivatives for possible use as cationic agents in paper and textile applications. Tetrakis-(hydroxymethyl) phosphonium chloride and 2,4-dichlorobenzyltris (diethylamino) phosphonium chloride were reacted with starch in attempts to prepare quaternary phosphonium derivatives. Other types of modified starches were prepared by reaction of starch with acetylmercaptosuccinic anhydride, chloromethyl-phosphonic dichloride, bis(gamma-chloro beta-hydroxypropyl) phosphite, and hexamethylphosphorus triamide.

6. High-amylose (HA) starch films and chemical derivatives. Films cast from chloroform solutions of high-amylose (HA) starch triacetate containing triethyl citrate plasticizer had clarity, tensile strength, and oxygen barrier properties comparable to those of unmodified HA starch film. Films

of good clarity and strength also were cast from 10-percent aqueous dispersion of HA starch acetate of D.S. 0.2-0.6. Methylated 99-percent-amylose films of D.S. 0.18 to 0.80 were water soluble. Methylated HA starches of D.S. 0.45-0.92 were prepared from Amylon VII (commercial 70-percent HA starch) under conditions of minimum degradation of the polysaccharide. The cold-water-soluble products of D.S. 0.7-0.9 had a diffuse crystalline X-ray pattern, while those of D.S. 0.2-0.4 had a "B" pattern and were hot-water soluble. Films prepared from hot-water dispersions of undegraded acetates of HA starch of D.S. 0.2-0.4 are clear and strong at moderate relative humidities, and retain good oxygen barrier properties. At R.H. below 20 percent, the films require plasticization with 40-percent glycerol to remain flexible.

7. Physical properties of starch. In studies under a contract with the University of Akron, zinc starch xanthate (ZSX) loaded SBR 1500 rubber stocks containing 0-100 parts per 100 parts rubber (phr) were prepared by zinc coprecipitation of starch xanthate with latex (latex masterbatching) and by dry mixing rubber with ball-milled ZSX. When incorporated by latex masterbatching, ZSX reinforced tensile properties of rubber vulcanizates, giving a maximum at about 25 phr loading. Ball-milled ZSX incorporated by dry mixing was nonreinforcing. Microscopic observation showed that maximum tensile strength in starch xanthate latex masterbatches occurred when all starch particles became submicroscopic. Ball-milled ZSX was present in larger particles and hence was nonreinforcing. ZSX in latex masterbatches also had a much higher degree of filler attachment compared to ball-milled dry incorporated ZSX. Rheometer studies on low-substitute ZSX latex masterbatches showed that the xanthate acted as a vulcanization accelerator.

Studies are being carried out under a PL 480 grant at the Slovenian Academy of Sciences and Arts, Ljubljana, Yugoslavia, on the modification of cereal grain starches by a variety of physical and chemical treatments designed to effect changes in their physical properties without destroying the granule structure in order to impart to the starches new and useful paste properties. Treatments performed on samples were: (1) Soaking in dilute acids or salt solutions; (2) heating under different moisture conditions at various temperatures, pressures, and times; (3) freezing under different moisture conditions at various temperatures; and (4) ultrasonic wave penetration of aqueous slurries at different frequencies and intensities. Generally, the various treatments of starches caused a decrease in their viscosity and swelling power, but an increase in their solubility. However, starches modified with sodium phosphate and zinc chloride show an increase in viscosity, swelling power, and solubility; whereas an epichlorohydrin treatment of the starches decreased all three. Of the starches investigated, wheat was the easiest to modify and high-amylose was the most difficult. The other starches were made more susceptible to modification by either defatting or presoaking in distilled water. No detectable difference was found between the X-ray patterns of native and modified starches.

During the year, experimental work on the preparation of starch pastes and exploratory rheological determinations made at paste concentrations of 5-15 percent was initiated under a PL 480 grant to the University of Graz, Graz, Austria. Three main lines of research are being investigated. These are (1) preparation of flow curves from several different types of viscometers, (2) thixotropic decay curves (time dependence), and (3) determination of gel strength and elasticity. The work is in initial phase in that methods for preparing starch pastes having reproducible viscosity characteristics have not been determined. However, some additional equipment which will be acquired should solve this problem. Nevertheless, from some 100 experimental curves, a so-called "diagram of state" for the pastes, in which viscosity is plotted versus the product of the shear rates and the shear stress with time as a parameter, has been prepared.

C. Microbiology and Fermentation

1. ARS Culture Collection. The organism Monascus purpureus is the predominant fungus on certain corn silages that caused cattle to "go off feed" and, in the literature, has been implicated in the death of horses. Large samples of cracked corn and corn meal, each fermented with isolates of this organism, were tested at the University of Illinois for feeding small calves. No evidence of toxicity was observed. Conditions were established for production of $\Delta^{\alpha,\beta}$ -butenolide by fermentation with Fusarium nivale. This toxic compound will be administered to calves in the search for the cause of fescue foot symptoms. In 1966, 2,092 cultures were sent from the ARS Culture Collection (1,558 to U. S. investigators and 534 overseas). The Collection was increased by addition of 196 strains to permanent collection and 1,115 to temporary collection, making a total of 33,381 strains in both collections.

Contract research by the American Type Culture Collection revealed that 95 percent of 104 fungi selected for testing, because they failed to withstand lyophilization, may be preserved for at least 18 months when frozen at -196° C. in 10-percent glycerol and stored in or over liquid nitrogen. Most of the others may be preserved if 10 percent DMSO is used as the suspending fluid.

Research of importance to the ARS Culture Collection is in progress at several foreign institutions under PL 480 grants. At the National Institute of Agronomic Research, Madrid, Spain, soil samples are being collected from various parts of Spain and are being screened for presence of streptomycetes elaborating antibiotics active against the plant pathogen Agrobacterium tumefaciens. Ten streptomycete cultures, along with supporting taxonomic data on each, have been received. In addition, extensive cultural and taxonomic data, including electron micrographs, on isolates of Streptomyces species have been received. Since our current need is for cultures rather than descriptive data on random isolates, the original project instructions are being amended to place greater emphasis on the screening of isolates for antibiotic-producing strains. With this revised procedure, a greater

number of cultures may be expected in the future from this source. The 10 strains received to date have been added to our antibiotics culture collection for use in future screening projects.

Soil samples are being collected from various parts of India and screened at the Central Drug Research Institute, Lucknow, India, for presence of streptomycetes elaborating antibiotics active against the plant pathogen Agrobacterium tumefaciens. Seventy-seven streptomycete cultures, along with supporting taxonomic data on each, have been received. Sixty-six of the cultures received have been checked for their ability to produce antibiotics by our methods, and 10 demonstrated activity against Agrobacterium tumefaciens. Twenty-one also were found to produce antifungal antibiotics, inhibiting the test organism Mucor ramannianus. The cultures have been added to our antibiotics culture collection for use in future screening projects.

At the University of Allahabad, Allahabad, India, cultures of Rhizopus arrhizus NRRL 2582, Aspergillus terreus NRRL 1960, Aspergillus niger NRRL 330, and Penicillium chrysogenum NRRL 1760 which produce fumaric and itaconic acids, amylase, and penicillin were investigated for yields of these products. In each instance, 100 spores were isolated at random from lyophil preparations and each isolate was used to make an appropriate fermentation. The yield of the product was determined. One hundred similar isolates were made from a nonlyophilized culture of the same strain and their fermentation products determined. Statistical evaluation of the results of the product yield established that no significant differences existed between the selections from lyophil preparations and the control fermentation. Further studies with microorganisms used to make streptomycin and gluconic acid gave similar results. It can be concluded that lyophilization has no detrimental effect on the capacity of organisms to yield the above fermentation products.

2. Taxonomic investigations. Studies on taxonomy of Mucorales have revealed a (-) strain of Rhizopus microsporus that produces zygospores when mated with the best tempeh-producing strain of R. oligosporus. This (-) strain, identified as R. microsporus on a morphological basis, mated with 22 of the (+) strains, giving from 2 to as many as 1,200 zygospores in a petri-dish mating, depending on the strain of R. oligosporus used. Agar slants of a nutritionally complete medium were inoculated with 202 strains of Rhizopus having small sporangiospores and were incubated at five different temperatures. All except three of the strains both grew and sporulated well at 37° C. All but one strain grew at 40° C., but 19 did not sporulate. Twenty strains did not grow at 45° C. and 50 more either did not sporulate or produced abortive sporangia. Only 71 strains grew at 50° C. and no strains grew at 55° C. Thirty-nine of our 42 strains of R. rhizopodiformis showed a maximum growth temperature of 50° C. However, there was no other close correlation between maximum growth temperature and present species designation.

3. Studies on enzymes. Genetic studies with the original diploid Hansenula holstii resulted in discovery of new homozygous mucoid diploids that produce phosphomannan having viscosity greater than that of the heterozygous parent. Haploid strains which produce even more viscous polymer were in turn obtained from the homozygous diploids. Use of these haploids in continuous fermentation would eliminate troublesome formation of non-mucoid haploids from heterozygous diploids.

Mannitol fermentations have been successfully conducted in 20-liter fermentors. Yields of d-mannitol are 40-50 percent based on the glucose consumed. The organisms used for this fermentation are selected strains of Aspergillus candidus. In the pilot plant, an economical process was devised to recover mannitol from the fermentation broth. This process involves crystallization from aqueous solution under controlled conditions. Preliminary cost calculation for product recovery only, to recover 3 million pounds of mannitol per year from fermentation broth, gave a recovery cost of 10 cents per pound of product. Kinetic studies on the two glucoamylase isozymes of A. awamori NRRL 3112 showed that the first one to appear in the culture has a greater affinity for starch and dextrin than does the second. It was also shown that these isozymes have different rates of glucose formation from starch. Transglucosidase from A. niger NRRL 330 has been isolated free from glucoamylase and has been found to make significant amounts of panose. Glucosyl glycerol has been highly purified and characterized; it contains an α -glucosidic linkage. Synthesis of 2-keto-3-deoxyglucaric acid by use of 6 units of glucaric acid dehydratase is linear over the range of 0 to 50 μ M of glutaric acid.

Microbial spore preparations tested showed considerable metabolic activity on several substrates. A. wentii spores were able to convert soluble starch to glucose; data indicate the presence of a glucoamylase rather than a β -amylase, since no maltose production was detected. Glucose production was influenced by temperature and pH; peak yields were attained in 3 days.

Grant research, completed during the year at the University of Nebraska, showed that the glucoamylase from Rhizopus delemar is similar in molecular weight and mechanism of action to the glucoamylase isozymes isolated from Aspergillus niger, but differs in that it contains significant amounts of glucosamine. The glucoamylases from A. niger appear to be immune to proteolysis by pronase and trypsin. A new glucanosyltransferase which transfers segments of α -1,4-linked glucose units was discovered in enzyme preparations from the bacterium Bacillus subtilis by the novel "oligosaccharide mapping" technique. Conditions were established for the production of glucoamylase with concomitant formation of minimal quantities of α -amylase and glucosyltransferase which will enable direct use of the relatively pure preparations of glucoamylase isozymes.

Under a grant to Kansas State University, substantial progress on the purification of enzymes has been made by refinement of the "stacking" procedure for preparative electrophoretic separations. With horse serum

as an example of a complex protein mixture, good separations of two esterases were obtained using nearly 1 mg. of serum. This is almost 60 times as much material as can be handled by ordinary electrophoresis techniques. One hundred forty milligrams of horse serum have now been fractionated with some success. Distortion of bands remains troublesome in larger scale runs because of convection currents caused by temperature differentials throughout the stacks.

At Iowa State University, also under grant, studies on the action patterns of Streptococcus bovis were broadened to include eight strains of the organism, and five different action patterns were found. A method for noting differences in action pattern was devised. Of the α -amylases so far examined, all but one show multiple attack with characteristic oligosaccharide formation. By use of a model system to follow the action pattern of α -amylase, it was found that the principal point of attack on maltoctose is at bond 2 or 3 from the reducing end.

Research was initiated during the year under a grant to the University of Arkansas. Results of studies on the mechanism of hydrolysis of cereal starches by enzymes have resulted in a reproducible method for obtaining cyclodextrin transglucosidase from Bacillus macerans. Nearly quantitative transfer of α -cyclodextrin to α -methylglucoside has been obtained. Progress is being made on scaling up the transfer reaction to obtain labelled oligosaccharides for testing with α -amylase from B. subtilis.

Studies establishing structures of peptide subunits in peptidoglycans from several lysine-containing bacterial cell walls are nearly completed. Through a series of sequential enzymic degradations, peptides were obtained from wall preparations. The tetrapeptide sequence N^{α} -(L-ala-D-iso-glutam)-L-lys-D-ala which occurs in apparent precursor uridine nucleotides was shown to be the basal peptide subunit in walls from a variety of organisms. Minor variations include the Micrococcus lysodeikticus peptide which contains a carboxy-terminal glycine residue in place of amide ammonia on the α -carboxyl group of glutamic acid, and Streptococcus pyogenes walls in which 10 percent of the subunits contain hydroxylysine in place of lysine. Considerable strain and species variation was found in crosslinks between wall peptide chains. These bridges between D-ala of one subunit and lysine ϵ -amino of another are responsible for the three dimensional wall network and its insolubility. The various bridges are: a direct D-ala- ϵ -N-lys link in M. lysodeikticus, (gly)₅ in Staphylococcus aureus, (L-ala)₃-L-thn in Micrococcus roseus R 27, (L-ala)₃ in another M. roseus strain, (L-ala)₂ in S. pyogenes, and N^{α} -L-isoasparaginyl in Streptococcus faecalis. This research is conducted under a PL 480 grant to the University of Liege, Liege, Belgium.

4. Biological insecticides for Japanese beetle. Bacillus popilliae spores, produced to the extent of 10-20 percent on a solid medium, are infective and cause milky disease when injected into larvae. Feeding tests indicate, however, that these spores are not infective when ingested from the soil.

The requirement for specific yeast extract and repression by carbohydrate of sporulation in liquid media containing carbon are identical to phenomena previously observed with solid media. These results indicate that an alternative energy source must be found to achieve good sporulation and that some unique nutrient is limited or out of balance. Heated spores produced on solid media increased infectivity by injection. Optimum temperature for activation appears to be 50-60° C. Spores so activated are almost 2.5 times as infective as unheated spores. Studies on oral infectivity show that larvae must be exposed to at least one billion spores per gram of soil for 21 days to achieve 50-percent incidence of milky disease. The oxygen requirements of healthy and milky larvae were found to be comparable. Hence, the depressed oxygen content of hemolymph during the pre-symptom stage of the disease is not fatal. During the course of milky disease, a protein having a molecular weight of about 300,000 disappears, whereas the concentration of a protein having 30,000 M.W. increases.

In the contract research at Baylor University, electron microscopy showed significant differences in the internal structure of vegetative cells from infected hemolymph and from laboratory cultures. These differences involve membrane organization and, therefore, are significant in sporogenesis. The structure of Bacillus lentimorbus spores is similar to that of Bacillus popilliae spores except that the wall layers are thicker and more dense. The refractile bodies frequently obtained in high yield with some B. popilliae strains consist of ghostlike vegetative forms with empty cytoplasm and accretions of electron-dense material without definite structure. Authentication of the structures formed in liquid medium containing carbon by B. popilliae confirms the first example of sporulation in liquid medium. Grossly distorted structure of most cells and the limited numbers and immature condition of the spores indicate that conditions are far from ideal. This system, however, can now be studied with the knowledge that these structures are not artifacts. Conversely, the concept that refractile bodies are spore forms must be abandoned.

At Michigan State University, enzyme activities of authentic spores, refractile bodies produced in culture media containing β -hydroxybutyrate (BHB), and vegetative cells of strain B-2309A were compared. It was found that vegetative cells contain no catalase, whereas spores from larvae contain a large amount of catalase activity, some of which is heat resistant. Refractile bodies grown in a medium containing barbituric acid likewise displayed partially heat-stable catalase activity. Enolase activity of larvae spores was much lower than that of refractile bodies produced in vitro in media containing BHB. A significant difference has been demonstrated in the metabolism of Bacillus popilliae strains B-2309M, B-2309A, and B-2309S. Strain B-2309M sporulates on agar to a considerable extent, B-2309S to a slight extent, while B-2309A only initiates sporulation and forms refractile bodies. Catalase has been found in strains B-2309M and B-2309A. The enzyme is formed in advance of refractile spores in B-2309M and during refractile body formation in strain B-2309A. This finding

indicates that refractile bodies are a consequence of abortive sporulation. Catalase is not found in young vegetative strains or in nonsporogenic strains at any growth stage. In freshly harvested cells, or extracts of them, the catalase is completely stable to 80° C. for 10 minutes. This work is being conducted under contract.

5. Microbial polysaccharides. Engineering studies on the relationship of oxygen demand to supply in B-1459 Xanthomonas campestris fermentations indicated that oxygen supply is not rate limiting. To investigate retention of vigor by B-1459 organism, fresh medium was added to an aliquot of a 48-hour fermented broth left from a preceding run. This back inoculation cycle was repeated 10 times over a period of 25 days. Results showed that culture retained most of its vigor and, therefore, that decreased vigor should not be a factor in continuous fermentation. Maintenance of stock cultures of B-1459 by a new procedure has overcome culture instability experienced in past fermentations. Polysaccharide productivity of the culture was good and viscosities 6,000 cp. were obtained in 48-hour fermentations. In a continuing effort to have a uniform polymer-producing microorganism, colonies of B-1459 were isolated and tested for polysaccharide production. An isolate, B-1459A, showed good polymer-producing capability.

A new modification of the carbazole analysis was developed for the measurement and identification of specific uronic acids in the presence of other uronic acids and/or neutral sugars. Structure of polysaccharide B-1973 has been established. It was found that the D-mannuronic acid moiety has the pyranoside form and that both the D-glucose and D-galactose moieties are glycosidically bonded at C₄. Also defined was the sequence of components in the component aldouronic acids. A vigorous producing culture of polysaccharide B-1828 has been developed and maintained; properties suitable for preliminary characterization of the product polysaccharide have been determined; and additional data pertinent to chemical structure were obtained. By an improved isolation procedure, a good supply of n-acetyl glucosamine polymer was obtained from growth medium of an unidentified yeast strain. Structural work on this polymer has revealed a neutralization equivalent of 740, indicating one acidic function per trisaccharide unit; acetyl of the acetamido function is the only identifiable acyl group after acid hydrolysis; acidity is not due to esterified sulfate or phosphate; polysaccharide is not oxidized by sodium periodate and thus is probably linked 1,3 throughout.

In studies on biphasic fermentation, under a grant to Cornell University, it was found that addition of Vitamin K partially reverses the growth of yeast by paraffin hydrocarbons. By coating either the microorganism or the solid surface with positively charged colloids, such as colloidal aluminum oxide, very strong adherence of the cells to a surface can be attained. This technique suggests possibilities for an improved fermentation method, cell coagulation, and increased resistance to lysis.

Under grant research at the University of Wisconsin involving studies of the fine structure of microbial polysaccharides, conditions were established for dispersion in organic solvents and carbanilation of polysaccharide B-1973. Selective hydrolysis of O-acetyl groups in the presence of O-carbanilyl groups has been investigated using the model compound 2,3-di-O-acetyl-4,6-di-O-carbanilyl- α -D-glucopyranoside.

6. Plant antibiotics. In tests on nine antibiotic preparations against 12 plant diseases and root nematode infestation, two were active against early blight of tomatoes, one against late blight of tomatoes, two against mildew of green beans, six against rust of beans, two against black spot of roses and three were effective in controlling certain soil fungi causing damping off diseases of seedlings; none was active in control of root knot nematode. These are in addition to the 10 stable non-polyenic antibiotics previously found to have promise for controlling economically important plant diseases. A new broad-spectrum antibiotic produced by several Alternaria species has been discovered; it has both antifungal and antibacterial activity.

7. Microbiological processes and products. Research on genetic modification of fermentation showed that diploids obtained by crossing haploid segregants of Hansenula holstii diploid Y-2448 produce phosphomannans differing qualitatively and quantitatively from those produced by the parents. The new diploids displayed poor sporulation so that further study of the genetic factors determining the kind and amount of phosphomannan produced could not proceed effectively. Ultraviolet-induced nutritional mutants of the parent strains were studied, but again sporulation was blocked in the constructed diploids. Attempts to derive breeding stocks which produce the normal complement of four spores per ascus have been unsuccessful. Recovery of all meiotic products from H. holstii asci containing only two spores indicates that secondary causes may be limiting formation of the expected four spores. The intensity of agglutination present in progeny from matings between moderately strong agglutinating H. wingei ranged from very strong through barely perceptible. Similar patterns appear in progeny of both mating types. Results suggest that agglutination is regulated by several factors which are not linked to the mating locus.

In the Pioneering Laboratory for Microbiological Chemistry, investigation of the genetic defect of Rhodospirillum rubrum that interferes with mutant identification on the basis of colonial morphology revealed that the lesion may result from a deficiency in d-alanine production necessary to form crosslinking wall precursors in the peptidoglycan layer. Further studies of ornithine lipid of R. rubrum indicated three classes of hydrolysis products: amino acid, polyols, and fatty acids and aldehydes. Fatty ester distribution on the polyols resembled the phospholipid fraction of R. rubrum, but the fatty acyl distribution resembled the bound lipids. Investigations on macromolecules responsible for agglutination of certain yeast strains

have revealed the disulfide bond structure is an important factor in the activity of the sex-specific agglutinin of type 5 Hansenula wingei. Fractionation (on Sephadex G-100) of the agglutinin in which the disulfide linkages had been broken by reduction yielded components having, respectively, sedimentation rates of 2S and 13S. Agglutinative activity was restored to a mixture of these components, but not to either singly, by dialysis in alkaline buffer. Therefore the structure of each component must be uniquely involved in the mechanism of agglutination.

In other work in the Pioneering Laboratory, differing yeast species are being surveyed to determine the prevalence of zymonic acid formation and the relationship to thiamine deficiency. New routes to the synthesis of 2-oxo-4,5 dihydroxyvaleric acid, a probable intermediate in the oxidation of L-arabinose by Pseudomonas saccharophila, are under investigation.

Under a contract to the University of Minnesota, an effort to determine whether the genetic elements of sporulation in Bacillus cereus T may be contained in an episome has resulted in finding a satellite DNA which appeared briefly in B. cereus T upon germination and before the first cell division. It could represent a genetic fragment in spores that are involved in control of sporulation and germination. Further work with DNA from three different phages and a variety of strains of B. cereus shows that B. cereus cells do not take in exogenous DNA. This species is, therefore, not suitable for study of genetic control of sporulation. It was found that in mixed culture with a Rhodotorula yeast, up to 18 percent of B. popilliae cells develop refractile bodies after 25 days. Addition of the yeast during the first 24 hours of culture was most effective; addition after 48 hours was practically ineffective.

At the University of Newcastle upon Tyne, Newcastle upon Tyne, England, research under a PL 480 grant has been completed and structural details of the teichoic acid (TA) extracted from Streptomyces griseus have been worked out. As has been found in TA from other actinomycetes, alanyl ester is absent although small amounts of ester-bound acetic and succinic acids were found. Various degradation techniques gave phosphodiester and monoester fragments which were isolated and characterized. The TA from S. griseus is unusual in that glycerol and ribitol phosphates occur in the same polymer. About eight ribitol units are linked as 1,5' phosphodiesters. Appended to some of the ribitol 3-positions are about 5 L- α -glycerophosphoryl side chains randomly distributed. Ribitol triphosphate and its degradation product, anhydro-ribitol diphosphate, were found, further indicating that some of the ribitol units bear more than two phosphate groups. No glycerol phosphate is present on the glycol end of the chain. β -D-glucosyl units are attached to the 2-positions of adjacent ribitol phosphates. Since no degradation product containing glucosylated ribitol phosphate linked to ribitol bearing a glycerophosphoryl has been found, two distinct TA's may be present, bearing glucosyl and glycerophosphoryl, respectively. The small amount of bound peptide present contains components characteristic of cell wall mucopeptide.

Last year it was noted that work had been completed under the PL 480 grant to the University of Milan, Milan, Italy. The final report, which was subsequently received, showed that in the strain of Acetobacter suboxydans tested, the two ketogenic enzyme systems which yield 2-ketogluconic acid and 5-ketogluconic acid were constitutive. The amount of these enzymes depended upon the physiological condition of the cell. These results mean that the enzymes for either product cannot be uniquely induced by specific substrates or other components in the medium. At the same time, the activity pattern of the enzyme systems make it impossible to choose cultural conditions in which one product is obtained to the complete exclusion of the other. Thus, it is concluded that formation of 5-ketogluconic acid as the sole fermentation product will require a strain which inherently lacks the capacity to form 2-ketogluconic acid. Such a strain will have to be obtained by selection of unique variants or induction of such variants by mutation.

8. Fermentation acids. In research at the University of Lodz, Lodz, Poland, irradiation of Aspergillus terreus by ultraviolet light or by gamma rays has yielded several strains which produce about three times as much itatartaric acid as does the parent strain. In surface fermentation yields as high as 6.5 g. per liter of itatartaric acid have been produced in 23 days in medium containing 17-19 percent glucose. Yields are not as high in submerged fermentations. Itatartaric acid and β -hydroxyparaconic acid are interconvertible at pH 2.0 and the equilibrium mixture is nearly 1:1 after 19 days at 35° C. Presumably the β -hydroxyparaconic acid found in A. terreus fermentations arises from itatartaric acid. None of the strains studied utilize itatartaric or β -hydroxyparaconic acids while all but one strain utilizes all the other organic acids formed during the fermentation.

Research on fermentation acids is in progress under PL 480 grants at several foreign institutions. At the University of Tokyo, Tokyo, Japan, factors affecting mevalonic acid production by the yeast Pichia membranaefaciens IAM 4032 were investigated. The best medium contained glucose, yeast extract, potassium phosphate, ammonium chloride, magnesium sulfate, and calcium carbonate. Glucose was the only suitable carbon source for mevalonic acid production with 0.1 percent yeast extract and 0.2 percent phosphate also required for optimum yields; other components were less essential. The highest yield was 150 μ g per ml. (130 μ g average) in 4-5 day fermentations. An isoprenoid produced by Trichothecium roseum Link IFO 5772 was also investigated. This compound was extracted with acetone from mycelia grown 96 hours in aerated fermentors using a glucose, peptone, yeast extract medium. The compound has strong antiviral activity against Newcastle Disease Virus strain Miyadera in cell culture and against Candida albicans. It has very low toxicity to mice. Infrared and ultraviolet spectra of the crystalline compound showed it to be tricothecin. Although known as a fermentation product, its antiviral properties were unknown.

In other research at the University of Tokyo, screening of freshly isolated organisms from soil has turned up additional organisms that appear to produce tartaric acid. Strains from three different genera have been found which produce significant amounts of the acid. Analytical methods for determination of tartaric acid have been refined. Both polarographic and photometric methods have been found to be satisfactory. Artificial mutants of promising strains have been prepared by UV irradiation and are being assessed.

At the National Sugar Institute, Kanpur, India, aldobi- and aldotriuronic acids are being isolated from plant gums in amounts sufficient for use as reference standards in NU research on microbial polysaccharides produced from cereal grains. Nearly completed is the series of aldobiuronic acid (isolated as the Ba salt): X-O-(β -D-glucopyranosyl uronic acid)-D-galactose (in which X is 6, 4, or 2). Also obtained has been X-O-(β -D-galactopyranosyl uronic acid)-hexose (in which X is 4 or 2 and the respective hexose is D-galactose or L-rhamnose). The remaining isolates to date are two triuronic acids containing 2-O-(-glucopyranosyl uronic acid) and 2-O-(-galactopyranosyl uronic acid), respectively. For each product, specific conditions have been established for the critical steps of partial hydrolysis of the purified gum by sulfuric acid, fractionation of the hydrolyzate on exchange resin, and purification by resin or paper chromatography.

D. Technology--Process and Product Development

1. Cereal xanthides and xanthates. The new 32-inch experimental paper-making facility has been calibrated and is considered fully operational. A wide range of paper products ranging from tissue to linerboard have been produced. A system for continually introducing additives to the pulp furnish has been developed, installed, and integrated into the total paper-making operation. Crosslinked xanthate has been continuously applied to kraft bag paper. Several NU-prepared cationic starches and flours applied at wet end provided strength improvement in paper handsheets similar to that obtained with commercial cationic starches, but starch graft copolymers did not prove as efficient as the commercial material. Performance of acid-modified wheat flour (AMF) as a surface size was good.

Investigations of redistribution of xanthate groups in starch xanthates were completed. This work was based on study of model compounds--the pure, isomeric 2-, 3-, and 6-O-(sodium xanthates) of methyl- α -D-glucopyranoside. When dissolved in 18 percent sodium hydroxide, the 2- and 3-isomers were converted to the 6-isomer which remained unaffected. The mechanism for this rearrangement is believed to depend on orthoester intermediates involving neighboring hydroxyl groups. Studies with amylose and model xanthides demonstrated that thionocarbonates are readily formed as decomposition products of xanthide. These studies support the proposal that such a thionocarbonate linkage might chemically bond starch to cellulose when starch xanthide is incorporated as a wet-end additive. When paper made with starch xanthide was treated with water at 80° C. for 90 minutes, all of the xanthide decomposed, while the high wet strength of the paper was unaffected.

CS₂ and elemental sulfur were formed. Infrared analysis of treated paper showed an absorption band characteristic for a thionocarbonate group and no absorption for a xanthide group. When the hot-water-treated paper was subjected to sodium carbonate solution (pH sufficient to destroy thionocarbonate), the resulting paper showed no wet strength.

2. Graft copolymers. Under a research contract, a 100-pound lot of starch-acrylamide (AA) graft copolymer has been prepared, characterized, and shipped to NU by Stanford Research Institute. Content of grafted AA was 18.3 percent, M_w for the grafted chain was 32,000, and grafting frequency was 1 per 880 AGU. At 25° C., aqueous pastes of this copolymer and the parent unmodified wheat starch had comparable viscosities at pH 5.5 and 10.5. Two other lots of AA grafted copolymers shipped to NU contained 7 and 18 percent grafted AA. Weight average molecular weight and grafting frequency in 7 percent product was 109,500 and 8,840, respectively. Corresponding values for the other copolymer was 222,000 and 6,100. Cost estimates, based on annual production of 5 million pounds of AA graft copolymers, give estimated selling prices of 24 and 28 cents per pound, respectively, for grafted copolymers with 7 and 18 percent grafted AA.

3. Starch derivatives for protective coatings. At Archer Daniels Midland Company, under a research contract, alkyd resins containing 40 to 70 percent oil (linseed or soybean) were prepared by reacting the alcoholysis products of glycol glycosides, glycerol, and soybean or linseed oils with various anhydrides of dibasic acids. Mixtures of succinic and maleic anhydrides gave the most promising results. Acceptable color was achieved by use of decolorizing charcoal during cook and by controlled addition of glycoside to cook. Workable viscosities were obtained by increasing excess hydroxyl content to 20 percent with glycerol. Four samples of alkyd resins (60-70 percent oil) were found to have film properties comparable to those of standard resins with regard to drying time, Sward hardness, and alkali resistance.

Under contract research at Battelle Memorial Institute, exterior and interior latex paint formulations were made with four starch derivatives as viscosity stabilizers. After 3 months' exposure, no major changes were noted in panels coated with the exterior formulations. Interior paint exposure after 1 month showed no major differences between control paint containing methyl cellulose as protective colloid and those made with the various starch derivatives. However, longer interior exposures to north light produced an increase in yellowing. Freeze-thaw stability results on the latex paints indicated that potassium carboxymethyl starch is as effective as methyl cellulose as a protective colloid.

4. Cyanoethylated starch. Corn starch absorbs sodium hydroxide from an aqueous solution according to a Freundlich isotherm. Studies over a temperature range of 4 to 55° C. showed that the Freundlich exponent varied little with temperature, and the coefficient decreased slowly with increasing temperature. Two different measurements of swelling have confirmed

that swelling is a function of concentration of alkali in starch after absorption, as well as temperature. The NU process for acid modification of soft white winter wheat flour was tested successfully in large-scale equipment of a flour mill. Product from one of the tests was successfully applied to paper as a surface size on the 32" paper machine. It required 50 times more acid to achieve the same rate of starch modification in an aqueous slurry as in dry-process modification with gaseous HCl.

At Western Michigan University, contract work on the use of cyanoethylated modified corn starches in paper processes is completed and evaluation is in process. The machine runnability of the cyanoethylated starches is comparable to that of the control commercial starches. Film properties of cyanoethylated starches are excellent with somewhat higher Hercules viscosity being compensated for by the higher thixotropy and leveling index of these starch coatings. All coated paper properties after super-calendering are comparable to those achieved with the various control starches with the exception that acid-modified cyanoethylated starch imparted much higher surface strength (pick resistance) and lower ink absorption. In the size-press study, acid-modified cyanoethylated starch was found superior to a commercial oxidized potato starch. In comparison to a hydroxyethylated starch, acid-modified cyanoethylated starch yielded papers of equivalent properties except for tensile strengths, fold, and smoothness.

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WHEAT UTILIZATION - FOOD

Northern Utilization Research and Development Division, ARS

Problem. The dominant factor in the wheat economy of the United States continues to be a production capacity that can outpace consumption, including the substantially expanded foreign markets of recent years. Increased exports of wheat from the United States in the last 3 years have brought our wheat carryover to a level that provides less than a prudent reserve. However, the capacity to produce wheat in this country is still restricted.

We view this North American surplus capacity as an unparalleled opportunity. Wheat in excess of domestic needs can be used to buy time in the overpopulated areas of the world until a self-sufficient agriculture can be developed there. Export donations and concessional sales of 600-800 million bushels per year are providing food where it is most needed in the world. This distribution of wheat serves immediate Defense and State Department missions, and also stimulates a long-range market development for United States agriculture. New wheat foods specifically adapted to conditions of use in every region of the world would help materially to popularize this valuable food grain in areas where it is now virtually unknown, and development of simplified methods to process the products at the point of use would speed their adoption.

We also need to increase the commercial exports (currently less than 200 million bushels annually) that contribute favorably to our international trade balance. New processes to elicit maximum quality performance of wheats and flours in products produced in Europe and Japan would help significantly to promote trade in these dollar markets. Sustained further gains in wheat markets are necessary to ease governmental restrictions on production more than they have already been eased, and especially to strengthen export trade balances. Increased world supplies of wheat and restrictive political decisions in the European Economic Community have contributed to seriously reduced commercial exports in some years. Everything possible must be done to increase total wheat markets, but especially those in which payments are made in dollars.

Consumers of wheat foods in this country have benefited greatly by introduction of a wide variety of new and improved products. Well-balanced diets, reasonable food costs, and improved convenience result from such developments and are suitable objectives of research. Domestic per capita consumption has become stabilized over the past 3 years. Research programs along these lines thus sustain and increase markets for wheat.

An essential foundation for a successful product and process development program is basic research on the composition of all classes of wheat and the fundamental properties of their constituents. This kind of information provides the foundation for improved and new products and processes.

USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing, long-range program of research involving analytical, organic, and physical chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic, applied, and developmental studies pertinent to utilization of wheat in food.

The Federal scientific effort (Northern region) for research on food utilization of wheat totals 7.9 scientist man-years. Of this number, 3.1 are devoted to chemical composition and physical properties; 4.2 to microbiology and toxicology; and .6 to technology--process and product development.

Research at Peoria, Illinois, on chemical composition and physical properties (2.1 scientist man-years) includes studies on separation and physical and chemical characterization of wheat proteins and on the microscopic and ultrastructure of wheat grains and flours and the effects of various treatments. A research contract (1.0 scientist man-year) is in effect with the Nebraska Agricultural Experiment Station, University of Nebraska, Lincoln, Nebraska, for investigations on varietal variations in kernel properties and milling and fractionation characteristics of wheat.

Research at Peoria, Illinois, on microbiology and toxicology (4.0 scientist man-years) is concerned with development of new fermented foods from wheat, with reduction of the microbial population of wheat and wheat flour and with studies on the production of mycotoxins by Aspergillus flavus and other molds. The work also includes a survey of the incidence of aflatoxin in commercial samples of various grains. A research contract in effect with the Agricultural Experiment Station, South Dakota State University, Brookings, South Dakota, provides for a survey of various species of Aspergilli to find and identify those producing toxic metabolites. A portion of this effort (.2 scientist man-year) is allocated to research on food uses of wheat.

Research conducted at Peoria, Illinois, on technology--process and product development (.6 scientist man-year) comprises investigations on modified techniques for milling and fractionation of wheat to obtain improved products for food. During the year, milling research was redirected to emphasize discovery and evaluation of new and unconventional approaches. Investigations on reducing radioactive contamination of wheat and wheat flour were successfully completed.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 14.8 scientist man-years is devoted to research on food uses of wheat.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Microscopic and ultrastructure of wheat. Studies have been initiated on the role of lipids in formation of gluten strands. Results to date indicate that native wheat protein produces much longer strands than does protein from which lipids have been extracted. Direct electron microscopy of wheat protein strands revealed that, in most cases, strands formed with flour particles on water surfaces were not sufficiently thin to provide adequate resolution. Numerous spherical electron dense bodies are frequently observed in association with fixed protein strands; the nature of these bodies and the conditions which lead to their appearance are not as yet clear. The strands were markedly reduced in length in all cases where flour particles had been previously defatted. Extensibility of wheat protein on tap water was appreciably greater than on distilled water. SRW wheat (Vermillion) forms finely subdivided protein strands in contrast to relatively coarse strands formed by HRW (Wichita) or HRS (Thatcher) wheats.

2. Crosses of soft and hard wheats. Contract studies on milling crosses between hard and soft Nebraska wheats at the University of Nebraska showed that treatment of hard wheat with enzymes specific for pectin and proteolytic enzymes resulted in milling properties resembling those of soft wheat. Previous conclusion that acid-soluble pentosans are not involved in milling efficiency still stands. Kernel penetration hardness tests or visual estimates of kernel vitreousness have little correlation with actual milling properties, whereas microscopic observation of endosperm breakdown caused by crushing a small specimen between two slides appears more reliable. Differences in relative amounts of protein fractions recovered by the Maes procedure indicate that mixing of dough prior to extraction introduces structural changes in flour proteins. Milling type could not be correlated with the results of the Maes procedure as modified to give improved electrophoretic patterns.

3. Characterization of wheat gluten proteins. Results, reported under "Wheat Utilization - Industrial Products," subheading A-1, are important to understanding the unique functional properties of wheat flour.

B. Microbiology and Toxicology

1. Reduction of viable microorganisms in flour and flour products. Dominant bacterial flora of domestic wheats and flours is, like that of the molds, limited to only a few genera. Total bacteria counts of wheats and flours from Texas-Oklahoma and southeastern U. S. were, in general, lower than those of samples from northern wheat-producing areas. Lactic acid bacteria constituted a very small part of the microflora of domestic wheat and flour. A practical method has been developed for producing flour with little protein damage and low microbial count from highly contaminated

wheat. Method involves steaming wheat for 15 seconds, quenching in cold water containing 250 p.p.m. of chlorine, dewatering, drying, and milling. The procedure can be used on a continuous basis and can be readily integrated into most mill flows. Studies on the microorganisms in dry-milled corn products have revealed a situation essentially analogous to that observed for wheat flour and milled fractions. Three potential processes for reducing microbial count in dry-milled corn products are being evaluated.

2. Fermented wheat foods. Rat-feeding experiments indicated that tempeh fermentation did not increase the protein efficiency ratio of soybean protein but did greatly increase the PER of wheat. No evidence of any kind of toxicity was found in these experiments. Diets containing a mixture of wheat and soybeans, either fermented or unfermented, as a protein source resulted in good body weight gain comparable to that of the reference casein diet. PER of the fermented mixture was essentially equivalent to that of casein. The patterns of essential amino acids released from wheat and fermented wheat by trypsin-pancreatin digestion reveal that greater amounts of lysine and histidine are released from fermented wheat than from control wheat. Satisfactory tempeh has been made from cracked low-fat peanuts and pressed peanuts. The majority of the tempeh mold strains were also found to produce a rennin-like enzyme which probably is the same proteolytic enzyme system previously reported.

3. Aflatoxin investigations. Studies on toxins produced by molds are important to utilization of wheat in food. Results are reported under "Corn Utilization - Feed," subheading B-1.

C. Technology--Process and Product Development

1. Milling and fractionation. Vacuum conditioning and concentrated spray treatment are both suitable means for lysine fortification of whole-grain wheat which is to be milled to 95 percent extraction for human consumption. Adding 2 percent lysine to wheat, the 95 percent extraction flour retained 82 percent of the added lysine. After applying 0.2 percent lysine by direct spraying, 69 percent of the added lysine was retained by the flour. Defatted, first oat flour (9.8% protein) showed a 50 percent protein shift, slightly more than for second oat flour (20% protein). These flours resemble hard wheat flour in response to air classification. Yield of high-protein first fraction was unusually large. The use of high temper moisture (22%) and prebreak milling, to help loosen protein from starch of HRW wheat, produced a small increase in break flour and overall flour yields.

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*Research supported by PL 480 funds.

WHEAT UTILIZATION - FOOD
Western Utilization Research and Development Division, ARS

Problem. The dominant feature of the wheat economy in the United States continues to be a production capacity that can outpace consumption, including the substantially expanded foreign markets of recent years. Increased exports of wheat from the United States in the last few years have brought our wheat carryover to a level that provides less than a prudent reserve. However, the capacity to produce wheat in this country is still restricted.

We view this North American surplus capacity as an unparalleled opportunity. Wheat in excess of domestic needs can be used to buy time in the over-populated areas of the world until a self-sufficient agriculture can be developed there. Export donations and concessional sales of 600-800 million bushels per year are providing food where it is most needed in the world. This distribution of wheat serves immediate Defense and State Department missions and also stimulates a long-range market development for United States agriculture. New wheat foods specifically adapted to conditions of use in every region of the world would help materially to popularize this valuable food grain in areas where it is now virtually unknown, and development of simplified methods to process the products at the point of use would speed their adoption.

We also need to increase and maintain the commercial exports that contribute favorably to our international trade balance. New flour-maturing processes to elicit maximum quality performance of wheats and flours in products produced in Europe and Japan would help significantly to promote trade in these dollar markets. Sustained further gains in wheat markets are necessary to ease governmental restrictions on production more than they have already been eased, and especially to strengthen export trade balances. Increased world supplies of wheat and restrictive political decisions in the European Economic Community have contributed to seriously reduced commercial exports in some years. Everything possible must be done to increase total wheat markets, but especially those in which payments are made in dollars.

Consumers of wheat foods in this country have benefited greatly by introduction of a wide variety of new and improved products. Well balanced diets, reasonable food costs, and improved convenience result from such developments and are suitable objectives of research. Research programs along these lines would sustain and increase markets for wheat.

An essential foundation for a successful product and process development program is basic research on the composition of all classes of wheat and the fundamental properties of their constituents. This kind of information provides the foundation for improved and new products and processes.

USDA AND COOPERATIVE PROGRAMS

Research on utilization of wheat for food seeks to solve the most urgent problems hindering the development of markets for the full productive capacity of U.S. agriculture. The emphasis is on (1) expansion of overseas dollar markets for U.S. wheats; (2) development of new wheat food products for long-term market development in food-short nations abroad; (3) raising the domestic consumption of wheat foods by increased variety, quality, and convenience; and (4) finding means to upgrade wheat millfeeds to recover fractions of nutritious food quality. Basic research on the fundamental chemical and physical properties of wheat and barley constituents and on the functional properties of wheat flour constituents supports the product development and problem-solving segments of the program.

Research is conducted by the Western Utilization Research and Development Division at Albany, California; under contracts and grants at Chicago, Illinois; Manhattan, Kansas; Madison, Wisconsin; St. Paul, Minnesota; Menlo Park, California; and Corvallis, Oregon; and under P.L. 480 grants in England, Australia, Switzerland, Japan, and Belgium.

The Federal program of research in this area totals 23.6 scientist man-years including six contracts and grants. Of this number, 6.5 are assigned to investigations on chemical composition and physical properties; 7.7 on color, texture and other quality characteristics; 3.0 on microbiology and toxicology; and 6.4 on technology - process and product development. In addition, the Division sponsors five research grants under Public Law 480.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 14.8 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Improvement of Baking Properties of Bread Flour by Controlling Maturation. We are studying the mechanism of wheat flour maturation to determine how maturing improves the baking properties of bread flour, and to develop maturing treatments for hard red winter wheat flour which will be acceptable in all dollar export markets.

We have demonstrated that phosphatidyl serine and the water-soluble proteins of flour form protein-metal-phospholipid complexes with magnesium, calcium, cobalt, and nickel ions. The protein components so complexed are specific with regard to metal ion, but methylation of the proteins destroys this specificity. Amino acid analyses show few differences between the complexed and non-complexed proteins, although threonine plus serine content is about twice as high in the complexed protein.

Procedures were developed for solubilization and chromatographic fractionation of water-insoluble hemicelluloses into five fractions of different composition. These procedures will permit assessing their function in dough and comparing flours.

We have observed that the amount of hydrogen sulfide released by doughs mixed vigorously under nitrogen differed at least 3-fold among samples of bread wheat flours. These results suggest that hydrogen sulfide may arise from one or only a few components.

Oxidative enzymes appear to be related to the mechanism of flour aging. Under a research grant, investigations are conducted at the University of Wisconsin to determine the role of native enzyme systems of endosperm in oxidative improvement of winter wheat flours and means of enhancing favorable mechanisms. Oxidative enzymes are being studied in hard red winter wheats and in hard red spring wheats. Indole acetic acid oxidase activity was found in the winter wheats only.

The enzyme lipoxidase is responsible for oxidizing lipids which are of importance in their chemical relationships with proteins and their effects on maturation of flours and mixing quality of doughs. When the activity of lipoxidase is high, we find that mixing tolerance is low, with the result that the dough breaks down quickly. Lipoxidase measurement could become an important specification for flours. Comparative measurements of wheat and soybean lipoxidase show that wheat lipoxidase, unlike soybean lipoxidase, showed little activity on fatty acid esters; both types were equally active on free fatty acids. Soy lipoxidase catalyzed the oxidation of polyunsaturated digalactosyl diglyceride lipids but only when trace amounts of linolenic acid were present; wheat lipoxidase was inactive under these conditions. If raw soy flour is added to wheat flour (as is sometimes done commercially), enzyme-catalyzed oxidation may affect many of the lipids of wheat flour and thus the mixing tolerance of the flour.

Free radical-generating oxidases caused aggregation of soluble proteins in model systems containing the oxidase, hydrogen peroxide, a hydrogen-donor, and a soluble protein. If occurring in dough systems, this reaction could affect mixing and baking properties.

Existing analytical methods for assaying riboflavin, in its many forms, were found to be unsuitable for use with wheat or flour. Under a P.L. 480 grant, the Agricultural High School in Poznan, Poland developed methods by which riboflavins in wheat and flour could be accurately determined. Flavins were shown to cause loss of activity of amylolytic and proteolytic enzymes when exposed to light. The involvement of sulfhydryl groups in this photosensitivity phenomenon was indicated. These studies also supported the view that riboflavin may regulate the activity of amylolytic enzymes in wheat during maturation of the grain.

2. Use of Malting to Modify Wheat Proteins and Other Constituents to Improve Nutrient Value of Foods. Contract research at the University of Minnesota in St. Paul is conducted to determine the nature and extent of changes in proteins and other major constituents of wheat that occur under malting conditions selected to produce desirable alterations in flavor, texture, and nutritive properties, but with limited conversion of seed solids to rootlets or acrospire. Certified seed of 8 wheat varieties has been malted at 2 temperatures (12° and 15° C.) and dried. Analysis shows that flour proteins change only slightly as a result of malting; but bran protein changes markedly. Malting greatly increases proteolytic activity; the nature of the proteases responsible is being studied. Other analyses indicate that amino acid patterns of flour proteins change little after malting, but in the non-protein nitrogenous fraction, aspartic and glutamic acids increase greatly; and alanine, phenylalanine, leucine, serine, threonine, and valine increase moderately.

B. Flavor

1. Bread Flavors. We investigated the chemistry associated with bread flavor to find means for enhancing and stabilizing flavor so that bread and other baked products will be more satisfying and desirable for consumers. We have obtained material with a strong cracker-like odor by reacting proline with glycerol. The same reaction was also shown to take place with sorbitol, glucose, and even glycerides. Gas-liquid chromatography examination of a bread-aroma concentrate and the semi-purified fractions of the reaction mixture revealed three peaks having a cracker-like odor. The retention time of one of these peaks was identical for both substances. Subsequent examination of this material gave a presumptive identity of 1-azabicyclo(3.3.0)oct-4-one. A second peak from the bread-aroma concentrate was tentatively identified as N-methyl-2-acetopyrrolidine. No identity was established for the first of the three peaks because of inability to collect enough sample material in a satisfactory state of purity. Continuing attempts to obtain enough sample for positive identification of all three of the odor-producing substances have involved forming a complex with bisulfite to stabilize the compounds.

Although bisulfite quenches the cracker-like odor properties of the purified fractions, the reaction is reversible. The compounds appear to be unstable, even at low temperatures unless stored as bisulfite complexes. This instability is reminiscent of the transient nature of the freshly baked aroma of bread.

Attempts to improve the flavor and aroma of bread by addition of a proline-dihydroxyacetone or proline-glycerol mixture were not entirely successful. Proline alone definitely improves bread, as was established under an earlier research contract. The reaction mixture, however, produced both good and bad effects, the latter presumably because of the side reaction products. Until the purified substances can be added to breads, a comparison with the effect due to proline alone will not be possible,

2. Civil Defense Fallout Shelter Rations. Research on food supply for fallout shelters is funded by transfer from the Office of Civil Defense, Department of Defense. An accelerated storage study on puffed bulgur stored in oxygen has shown that initial rate of off-flavor development is related to an increase in carbon monoxide and hexanal. However, the initial odor change was not considered objectionable or typically rancid. Pentane appeared in detectable amounts well after the initial off-flavor development had first appeared but has not increased significantly (102 days). Since the puffed bulgur is still not considered rancid, it is possible that continued storage will show a relationship between pentane accumulation and rancidity. Concentrations of oleic, linoleic, and linolenic acids were found, within experimental error, to be the same in flour, bulgur, and puffed bulgur (18%, 50%, and 4%, respectively).

Determinations of hexanal and carbon monoxide production will be useful for objective non-destructive surveillance tests of stored shelter wafers. Further work will be required to determine whether these compounds, plus pentane, show a correlation with organoleptic rancidity development in puffed bulgur. The successful development of an objective test to judge the condition of food products also will have considerable applicability for providing consumers with products in good condition. Although developed for use with bulgur containing products, the method should be equally applicable to other fat containing foods in which linoleic acid is the principal fatty acid component of the fats. The rapid, non-destructive, and objective character of the test thus will help maintain cereal and other food consumption by assisting in providing consumers with high quality products.

C. Color, Texture and Other Quality Factors

1. Improved Quality of Baked Goods Through Study of Wheat Proteins and Their Interactions with Flour Components and Dough Ingredients. Wheat proteins are known to have a major influence on the physical and structural characteristics of doughs and baked products, but how these proteins exert their effects is not known. Therefore, in addition to investigating the composition and physical properties of proteins, we are especially interested in their interactions with other components of flour and dough.

The effect of proteins on the functional properties of wheat flour and dough is under investigation. We have found that alpha-gliadin molecules can aggregate, at pH 5 in low salt concentrations, to form soluble, high-particle-weight fibrils of a uniform width, suggesting that some rheological properties of doughs may depend on this aggregation. The fibrils have been found in acidic flour extracts and in purified alpha-gliadin solutions.

A "globulin" component of flour moves with the same high mobility in zone electrophoresis as does purothionin, a low-molecular-weight protein extracted from flour by lipid solvents. The globulin component was found to have a high cystine content and other properties characteristic of

purothionin. The apparent identity of the two components suggests that globulins may participate extensively in lipid-protein complex formation. We have devised a sensitive technique, based on simultaneous ultraviolet absorption and fluorescence monitoring, for determining the homogeneity of fractions. The method has shown the presence of five components in a preparation where either ultraviolet absorption or fluorescence used alone showed only two. This technique should be applicable to many protein isolation problems. A program to determine the relationships between dough properties and protein interactions has been initiated.

In contract research conducted at Washington State University, the fate of extractable proteins was followed by the use of radioactive tracers. Radiotracer-labeled wheat from growth chambers had an abnormal flour protein distribution very low in gliadin components. Field-grown labeled wheat was normal in flour protein distribution. Variations in nitrogen and light supply did not account for the low gliadins in growth-chamber wheat. Results from incorporation of four labeled protein fractions in flour-water doughs and fermented doughs showed only one significant change in distribution of tracer label; under-mixed flour-water doughs behaved as though lower-molecular-weight components had been formed from high-molecular-weight gluten components. Optimum- and over-mixed doughs did not show this. This result needs confirmation because it does not agree with results of other work on solubilization of dough components with mixing.

A study of proteins and lipids of spring and winter wheat flours to identify differences responsible for their differing response to oxidative maturing treatments has been concluded at Kansas State University. Pentosan preparations from a durum flour differed from those from other types of wheat in carbohydrate composition, electrophoretic mobility of associated proteins, and infrared spectra. All pentosans decreased dough-development time and dough stability. Durum pentosans lowered, but others increased or did not affect amylograph peak viscosity. Added pentosans increased oxidation requirements of doughs. Loaf volumes were increased by hard red winter and club pentosans, but decreased by soft red winter and durum pentosans.

We have concluded a study of the compositional factors of wheat flours which limit the percentage of nonfat dry milk solids which can be satisfactorily used in continuous-mix processes for bread production. We demonstrated that wheat flour contains a surprisingly active specific protease which, at slightly acidic pH, rapidly attacks the α_s -casein component of nonfat dry milk.

The presence of a protease in flour that attacks specifically α_s -casein of nonfat dry milk proteins suggested that doughs containing nonfat dry milk or α_s -casein be compared when the nonfat dry milk or α_s -casein had and had not been present in a brew together with flour. The results indicated that the action of flour protease and α_s -casein was of minor importance to continuous mix bread production. When brews contained no

flour, or only 10% flour, 6% nonfat dry milk as expected consistently caused decreases in crumb score and loaf volume. When 0.28% α_s -casein replaced 4% nonfat dry milk (which would contribute 0.28% α_s -casein), adverse effects were no longer observed. A volume increase usually was obtained, even when the α_s -casein was hydrated separately from the brew and added at the dough mixing state. With brews containing 30% flour, in contrast, α_s -casein in the brew had no effect unless hydrated separately, when it gave a small volume decrease. The decrease was not as great as that caused by the equivalent amount of nonfat dry milk however.

We made measurements of the loss of sulfhydryl groups from doughs containing nonfat dry milk during 20 minutes mixing. The addition of nonfat dry milk in amounts up to 6% of flour weight progressively reduced the loss of sulfhydryl groups, with the effect being much more marked at pH 5, about the pH of continuous-mix doughs. Above 6% nonfat dry milk, however, the trend was reversed, both at pH 5 and with pH unadjusted. Results with four flours were very similar and consistent, although absolute changes during mixing were small.

We studied the effects of nonfat dry milk on the release of hydrogen sulfide from doughs mixed under nitrogen. Three samples of nonfat dry milk were used--a high-heat commercial product for bakery use, a low-heat agglomerated product for home consumption, and a freeze-dried nonfat dry milk prepared in the lab from pasteurized skim milk. When added at 6% of flour weight to either a commercial spring or winter wheat bread flour, the high-heat nonfat dry milk doughs released more hydrogen sulfide than doughs containing the low-heat solids. The effect of 6% high-heat nonfat dry milk did not quite equal that of an additional 6% flour; but the difference between nonfat dry milk preparations was so marked that the doughs containing 6% low-heat nonfat dry milk released less hydrogen sulfide than control doughs (with no added flour or nonfat dry milk). The data suggest that the increased availability of sulfhydryl groups in high-heat, as compared to low-heat, nonfat dry milk may permit more ready incorporation of the high-heat nonfat dry milk proteins into films of flour proteins; on the other hand, the difference may reflect only a difference in water-absorbing capacity which changes dough consistency.

Illinois Institute of Technology Research Institute is conducting contract research to determine the macromolecular structures present or developed in flours and doughs to improve control of dough properties and selection of flour. Transmission electronmicrographs of dough showed large stained areas predominantly proteinaceous, which suggests that the network-type protein structure in flour had been stretched. Unaffected starch granules were present, but their original distribution relative to other components had been changed. Diffuse staining around granules suggests that doughing leaches starch components out of granules to a significant extent. In contrast to flour, dough sections show no structural organization. Scanning electronmicrographs show flour to have cleavage lines due to milling. Starch granules have smooth surfaces, with occasional patches of adhering

protein. The pervading proteinaceous matrix has rough, broken, and curled edges where it is broken up during milling. In dough, the protein is transformed into a smooth, veil-like network stretched over the starch granules. Some granules seem to adhere to the surface of the protein continuum, but others are completely enveloped.

We have initiated a program to improve the baking properties of reconstituted bread doughs by modifying wheat starch granule preparations and the adhering proteins, lipids, and hemicelluloses.

Research at Osaka Women's University, Osaka, Japan, is supported by P.L. 480 funds. In studies conducted there, the viscoelastic properties of wheat proteins are varied in an attempt to clarify the mechanism of dough-forming properties of flour. Analyses indicate that the reaction of gluten with polymers is stoichiometric with respect to the acidic groups of the polymer and the basic groups of the protein. The mode of combination may be through a salt linkage. At equal ionic levels, polyvinyl sulfate showed small and carrageenan moderate positive effects on the extensibility of dough. Increased stability, but slightly reduced consistency resulted, these modifications result in generally better dough characteristics. Sulfhydryl-chitosan and polyvinyl thioglycolate showed dough weakening similar to that due to cysteine and thioglycolic acid.

Under a P.L. 480 grant, the Centre National d'Assistance Technique et de Recherche Appliquée, Antwerp, Belgium, is conducting studies to determine the isopropanol-soluble proteins from wheat that correlate with baking quality, evaluated by European methods, and with response to improvers. Characterization of 24 wheats for 9 physico-chemical properties is completed. Ground samples were extracted and nitrogen and total solids were determined. Results indicate that the gliadin/albumin ratio is type-dependent, and variably lowered by n-butanol treatment; the gliadin/glutenin ratio does not vary with type of wheat, with or without butanol treatment. Butanol treatment reduces the amount of protein extracted with 40% isopropanol but enhances its purity and protein soluble in 40% isopropanol increases with protein content of wheat and is slightly higher in winter than in spring wheats.

A P.L. 480 grant to the Pasteur Institute in Paris, France, has been concluded. Proteins of barley and wheat were studied, with particular emphasis on immunochemical methods of analysis. Barley proteins were resolved into 17-22 constituents. Barley and malt beta-amylase were in the albumin fraction, and malt alpha-amylase in the globulin fraction. No precursor of alpha-amylase was found in ungerminated barley, and apparently the enzyme is formed de novo during germination. Alpha- and beta-amylase were purified to the point at which monospecific antisera could be prepared from them. Proteolytic activity was described and partially located among fractions. The salt-soluble wheat proteins were resolved into 10 constituents. Protease activity was richest in those components moving

most rapidly to the anode at pH 8.2. Immuno-electrophoretic analysis of 3 varieties showed only quantitative differences in protein components. The 'insoluble' wheat proteins (gliadin, glutenin) showed antigenic identity, but were electrophoretically heterogeneous. It was concluded that the insoluble proteins probably have similar sub-units and that the antigenic sub-units were linked covalently but not primarily by disulfide bonds. Phosphorylated groups were found in glutenin and gliadin.

A study of insoluble gluten by application of ultrasonic vibrations to suspensions of the protein has been concluded. The work was conducted at the National Institute of Agronomic Research in Paris, France, supported by P.L. 480 funds. A series of flours, acidic extracts of the flours, and glutens from them comprised the experimental material. Effects obtained varied with the frequency of the irradiation, and in general, effects were greater in magnitude for dispersions of gluten than for the wet gum gluten itself.

Glutens from untreated flours appeared to be partly degraded by the irradiation in that the fraction emerging first from ion-exclusion columns was diminished in quantity, but solubility and viscosity decreased. The higher frequencies used were the most effective in producing the changes. Removal of water- or salt-soluble proteins from flours before separation of glutens led to divergent effects. Results with glutens from flours without water soluble protein suggested that aggregation effects accompanied degradative effects. Glutens from defatted flours were more sensitive to the ultrasonic radiation than the gluten from untreated flour. Low- to mid-range frequencies were most effective in causing a decline in quantity of both high and low molecular weight fractions coming off ion-exclusion columns.

Under a P.L. 480 grant, the Swiss Federal Institute of Technology at Zurich, Switzerland, is studying the nature of soluble pentosans, their mode of linkage to proteins, and the role of polyphenols in forming gels from aqueous extracts of wheat flour. A highly active purified xylanase was isolated from a crude cellulase preparation. A xylanase digest of a starch-free, non-gelling pentosan fraction showed xylose, arabinose, and galactose present in the acetone-precipitated portion after acid digestion; the filtrate yielded xylose and some higher oligomeres. Viscosity of a pure arabinoxylan fraction incubated with the enzyme decreased rapidly over the first 20 min., but viscosity of flour suspensions decreased much more slowly.

Caffeic acid esters of starch were successfully prepared as models of naturally occurring polyphenolic-polysaccharide complexes. Three degrees of substitution were obtained: 30, 8, and 0.4 caffeic acids residues per 100 glucose units; the last two were water soluble. Measurements of ferulic acid in wheat flour indicate 2 esters for each 100 xylose units, if all the ferulic acid is located in the xylan portion of the glycoprotein.

The Flour Milling and Baking Research Association at Chorleywood, England, supported by P.L. 480 funds, has concluded a study of means of solubilizing gluten proteins so their component parts may be better understood. Procedures were successfully developed to solubilize the total protein of wheat flour with no apparent rupture of any covalent linkages, other than disulfide bonds. This necessitated careful adaptation of prevailing sulfitolysis procedures and use of milder than standard conditions. At pH 8.6 substantial disulfide-sulfhydryl group radical interchange was induced with low molecular weight thiols, so that effects of alterations in patterns of reactive side groups on protein properties can be studied. Limited comparison of thiol and disulfide bond accessibilities in a strong and a weak flour showed the stronger flour to respond more quickly, and to a greater extent, as urea concentrations were increased to promote accessibility. Heat denaturation of flour proteins did not alter the accessibility patterns. In confirmation of reports based on other methods, gliadin disulfide linkages were shown to be largely, if not completely, intrachain. Other flour proteins had a much greater content of interchain bonds.

Under another P.L. 480 grant, the Flour Milling and Baking Research Association in Chorleywood, England, is investigating the nature and extent of interactions between lipids and other major dough constituents and how they relate to the structure of baked goods. Six categories of lipids in doughs seem to relate to binding forces: 1) mechanically expressible, 2) non-polar-solvent extractable, 3) water-miscible, weakly polar-solvent extractable, 4) electrostatically bound, 5) metal-chelated, and 6) firmly bound (extensive polar-solvent extraction). Time of fat addition during dough mixing did not affect the proportion of free (ether extractable) and bound (water-saturated butanol extractable) lipids nor the phospholipid binding. Neither did rate of work input change free/bound lipid; total work input alone was the controlling parameter. Lipid/gluten ratios in doughs did not relate entirely to protein content of strong and weak flours. Much more lipid was associated with the starch fraction in weak flour than in strong flour. Nitrous acid treatment of flours produced no shift in free/bound lipids, but it reduced bound phospholipids. When long-chain saturated hydrocarbons were used as the fat component in doughs, loaf volumes increased with increasing chain length. The effect appeared within flours, but differed widely between flours, which indicates important flour-fat interactions and contradicts the hypothesis that improvements depend only on physical properties of fat. To study lipid protein complexes, purothionin has been prepared and characterized. A second fraction from the petroleum ether extract also shows ester and amide absorption in the infrared, indicative of the presences of other lipoproteins.

Contract research at Stanford Research Institute in Menlo Park, California is conducted to relate the molecular organization in wheat flour doughs to baking characteristics. Stress-strain data were obtained for doughs of a bread flour and of a pastry flour at several moisture levels, temperatures, and rates of extension. An equation representing the

behavior of the doughs expresses stress as a function of a material parameter and contains a strain-independent function of time, as well as a time-independent function of strain. The material parameter is the constant strain rate modulus at a suitably chosen time, at the reference temperature T_0 and reference water absorption W_0 . The time function is $(t/a_T a_W)^x$ where a_T and a_W are empirically determined shift factors which reduce to unity at the reference conditions of temperature and water absorption. With this expression, stress-strain behavior could be linearized up to extension of 180% for the bread flour, but only to about 80% for the pastry flour. The time dependence of the constant strain rate modulus also differed; for the bread flour, $x = 0.29$, for the pastry flour, -0.40 . Other differences appeared in the true stress at break and in the area under the stress-strain curves. The large deformation results show that doughs of different water contents and at different temperatures can be compared and indicate several parameters for comparison. Thus far, elastic forces appear to contribute prominently to the stress-strain behavior even though dough is readily deformed.

Supported by P.L. 480 funds, the Bread Research Institute of Australia in North Ryde, Australia is conducting research to determine viscoelastic properties of doughs, and relate the properties to behavior of doughs in current empirical instruments and in new commercial procedures. An instrument was designed to study rheological properties of doughs over a range of frequencies. Stress-relaxation behavior was derived for times as short as 0.001 second. At low strains, dough viscoelastic behavior was linear but at higher values it became increasingly non-linear. In the linear range, a temperature-frequency superposition principle was established, making possible separation of dependent variable responses by reference to a common temperature. Similarly, a water absorption-frequency superposition principle was established. Thus any given set of dough properties can be reproduced by varying the water absorption. The simplicity of these relationships suggests that variations in viscoelastic properties of gluten are modified and minimized by the large proportion of starch in doughs. Therefore, interactions of gluten and starch may be important in explaining differences among doughs.

2. Carrying Capacity of U.S. Hard Winter Wheats for European Soft Wheats in Bread Manufacture. In order to strengthen the competitive position of U.S. wheat in export markets, contract research at Kansas State University is conducted to determine and quantitate the properties of U.S. hard red winter wheat flours of value in blending with weak flours to obtain optimum baking performance. All 1965-crop wheat samples, including a Canadian wheat of 13.5% protein were milled. However, delayed receipt of European samples precluded completion of analysis. Hagberg "falling number" values were illustrative of the problems encountered with European wheats: 1964-crop flours ranged from 232 to 638 and 1965-crop from 151 to 458. Values for U.S. wheat are from 493

to 876. Low values are indicative of excessively high alpha-amylase content which is caused by sprouted grains commonly present in European wheat.

D. Microbiology and Toxicology

1. Improved Quality Retention in Frozen Fermented Doughs. We seek to increase the quality and consumer acceptance of frozen fermented doughs by determining the factors which affect the quality of frozen doughs. We prepared frozen bread dough by the straight dough method and stored it for 6 weeks at 0° F. A short fermentation time (30 minutes or less) was adequate for stability as measured by residual yeast count, gassing power, proof time and bread volume. Increasing the yeast level from the conventional 2 or 3% to 6% was of further benefit in shortening proof time. Longer fermentation times, in addition to causing poor yeast stability, also yielded weak or slack dough with poor gas-retention properties. Addition of approximately 40 ppm of potassium bromate largely corrected the weakness-of-dough defect, but was of no value in improving yeast stability or proof time.

Doughs prepared by the sponge and dough method and stored for 6 weeks at 0° F. exhibited very poor stability by all indices. Spiking with additional yeast at the second (or dough) stage was of little benefit. The following changes in procedure markedly improved stability: adding non-fat milk solids to the sponge mix, reducing the sponge time from 4 hours to 1 hour, and chilling the sponge before mixing the dough. Spiking with additional yeast at the dough stage was then of substantial benefit and, in fact, essential, when combined with one or all of the above changes.

E. Technology--Process and Product Development

1. Development of Protein-Enriched Foods from Wheat Flour and Millfeed Fractions and Concentrates. We are conducting research to develop methods for obtaining protein concentrates from millfeeds for human food. Protein concentrates prepared by various methods were compared. One protein concentrate was prepared by rollermilling and sifting of shorts at 9% moisture content. The protein efficiency ratio of this concentrate was 1.9 and lysine content was 4.2 g/16 N. Thiamine, folic acid, and choline were increased in the protein concentrate, while riboflavin, panthothenic acid, niacin, and pyridoxine were reduced. All vitamins were present at 3 to 38 times the concentration found in unenriched, white flour. High moisture content (13-15%) in shorts before milling resulted in protein concentrates of low yield and low lysine, thiamine, and riboflavin contents. At milling moistures of 9 to 11%, protein content of the protein concentrate was at a peak, fiber content was low, and yield, lysine and thiamine were all at high levels. Finer sieves produced protein concentrates that were very low in fiber, but yields were cut sharply, and the contents of thiamine, riboflavin, and lysine were lower. Various analyses suggest that endosperm and germ tissue are concentrated in the protein concentrates from shorts,

while pericarp and aleurone are reduced. Commercial germ showed a great increase in friability at 9% moisture compared with 15% moisture.

We are developing milk-like and meat-like products from native or modified wheat and wheat proteins. We have developed a new, inexpensive method for nearly complete separation of protein and starch in wheat flours with no loss of soluble solids and consequently reduced waste problems. Bread baked from the recombined protein and starch was about 15% lower in loaf volume than bread made from starting flour.

The utility in foods of protein concentrates from wheat milling by-products was shown by the development of an inexpensive, nutritious and palatable beverage product prepared by amylase digestion of a blend of the high protein and standard flours fortified with minerals. The product compares favorably with other similar low-cost products.

2. Expand Foreign Markets by Developing New Non-baked Cereal Products of Improved Quality and Nutrient Content. The world food deficit is a continuing threat to international peace and economic security. Great opportunities exist to process and distribute new food products tailored to the needs and habits of specific foreign populations, to build and sustain commercial markets and to provide acceptable foods at lowest costs.

WURLD wheat, developed at the Western Lab, is an example of these new food products. It is a whole kernel or cracked kernel product from which the bran has been removed by lye-peeling. WURLD wheat has been tested by Church World Services for acceptability in Hong Kong. The product is not objectionable to any considerable proportion of the Chinese eating it there, even though served repeatedly. It was well accepted, although less well than the very familiar foods. A similar test in Madras, India, under CARE is still unreported. A market test is to begin soon on Guam among natives of principally Filipino origin. Extensive commercial exploitation is proposed if the test results are favorable.

For the consideration of AID, we collected data on the nutritive properties of WURLD wheat. On the basis of protein quantity and water soluble vitamins, the new product ranks well above white flour--even high extraction flour--and rice. It is very slightly inferior to raw wheat or bulgur in vitamin content and protein quality.

Contract research at Oregon State University is conducted to identify compounds in wheat bran and aleurone that impart color to these tissues, as a guide to developing light-colored wheat foods. Gas chromatography studies have been initiated to quantitate reference phenolics and show complexity of the phenolic-type of compounds found earlier in bran extracts. It has been found that nitrogen occurs in a major colored bran extract.

Two other studies are being conducted to increase world food supplies. We are developing economic methods to recover protein from millfeeds to increase

the supply of edible protein. By rollermilling and sifting of shorts at 9% moisture content, we have developed a protein concentrate with a protein efficiency ratio of 1.9 low fiber content, and high levels of lysine, thiamine and yield.

Also, we are conducting research to simulate milk and meat in dry and moist forms from combinations of native and modified wheat and wheat proteins and other flavor-, texture-, and nutrition-enhancing materials for specific export and domestic markets. We have developed an inexpensive, nutritious and palatable beverage product prepared by amylase digestion of a blend of high protein and standard flours fortified with minerals.

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WHEAT UTILIZATION - FEED

Northern Utilization Research and Development Division, ARS

Problem. In the last 2 years the use of wheat for feed increased to nearly 100 million bushels per year, more than twice the amount used in any other recent year. Unfortunately, wheat has certain performance drawbacks as a feed. Research that develops new processes to improve feeding quality of wheat will benefit both growers and feeders in wheat-producing areas, since it will place this grain in a more competitive position as compared with other grains, and it can reduce freight costs.

Millfeeds are not used extensively in modern poultry and swine rations because the high fiber content cannot be tolerated in high-energy rations. If inexpensive ways of separating low-fiber, high-protein fractions from millfeeds are developed, these new materials can be used as protein and energy sources for nonruminant diets, and the overall value of milling by-products will be increased. Flour production is expected to increase in the near future to reflect the demands of our increasing domestic population and of the new export markets which are developing. More milling will result, of course, in more millfeeds. If these millfeeds cannot be utilized efficiently and effectively, the price for flour will have to increase to carry the economic burden.

Meat production, particularly poultry, is increasing rapidly in Japan and the European Economic Community where modern efficient methods have been introduced. This development depresses the opportunity for exporting poultry and other meats into these important trade areas, but it offers an increasing opportunity to sell feeds. Upgrading of wheat millfeeds through utilization research will increase our export markets.

USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing, long-range program of research involving analytical, organic, and physical chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic, applied, and developmental studies pertinent to utilization of wheat in feed.

The Federal scientific effort (Northern region) for research on utilization of wheat in feeds totals 1.8 scientist man-years, of which .3 is devoted to chemical composition and physical properties; 1.2 to microbiology and toxicology; and .3 to technology--process and product development.

Research at Peoria, Illinois, on chemical composition and physical properties (.3 scientist man-year) involves basic investigations of the microscopic and ultrastructure of wheat grains and the effects of various treatments.

Research at Peoria, Illinois, on microbiology and toxicology (1.0 scientist man-year) is concerned with studies on the production of mycotoxins by Aspergillus flavus and related molds. A research contract (.2 scientist man-year*) is in effect with the Agricultural Experiment Station, South Dakota State University, Brookings, South Dakota, for survey of the genus Aspergillus to find and identify species producing toxic metabolites. During the reporting period, research was completed at A. D. Little, Inc., Cambridge, Massachusetts, for studies on stabilization of fermentative β -carotene, and with Consolidated Laboratories, Inc., Chicago Heights, Illinois, for research on the use of antimetabolites to facilitate selection of higher yielding strains of microorganisms producing β -carotene.

Research conducted at Peoria, Illinois, on technology--process and product development (.3 scientist man-year) is concerned with studies on modified techniques of milling and fractionation to obtain improved products. During the year, milling research was redirected to emphasize discoveries and evaluations of new and unconventional approaches. Investigations on reducing radioactive contaminants of wheat and milled fractions were successfully completed.

The Department also sponsors research in this area conducted under grants of PL 480 funds. Research on microbiology and toxicology involves a grant to the Agricultural University, Poznan, Poland, for studies to increase the yield of β -carotene produced by fermentation of cereal grains (4 years, 1966-1970). Effort on this project is prorated among corn, wheat, and sorghum.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of .6 scientist man-year is devoted to research on industrial and feed uses of wheat.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Studies on the microscopic and ultrastructure of wheat are relevant to utilization of wheat in feeds. Results are reported under "Wheat Utilization - Food," subheading A-1.

B. Microbiology and Toxicology

1. Aflatoxin investigations. Studies on toxins produced by molds are important to utilization of wheat in feeds. Results are reported under "Corn Utilization - Feed," subheading B-1.

*Work covers more than one commodity; only effort allocated to wheat is included in total.

C. Technology--Process and Product Development

Research on milling and fractionation of wheat and on reduction of radioactive contamination in wheat and milled products is relevant to utilization of wheat in feeds. Results are reported under "Wheat Utilization - Food," subheading C.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None.

WHEAT UTILIZATION - FEED

Western Utilization Research and Development Division, ARS

Problem. Wheat can now compete with feed grains as animal feed because recent legislation on wheat pricing makes it economically feasible. In the last two years the use of wheat for feed increased to over 100 million bushels per year, more than twice the amount used in other recent years. Projected usage for 1967 again is slightly higher. Unfortunately, wheat, especially Western wheats, has certain performance drawbacks particularly as a feed for poultry. Research to improve the feeding quality of wheat would greatly benefit both growers and feeders in wheat-producing areas, since it would place this grain in a better competitive position with other grains.

Millfeeds are not used extensively in modern poultry and swine rations because the high fiber content cannot be tolerated in high-energy rations. Ways to separate low-fiber, high-protein fractions from millfeeds have been developed. If these new materials can be produced cheaply enough, they can be used as protein and energy sources for non-ruminant diets, and the overall value of milling byproducts will be increased. An alternative approach is to increase the digestibility of millfeeds by process treatments such as steam pelleting or enzymatic supplementation or digestion. Flour production is expected to increase in the near future to reflect the demands of our increasing domestic population and of the new export markets which are developing. More milling will result, of course, in more millfeeds. If these millfeeds can be utilized efficiently and effectively, the price for flour will not have to increase to carry the economic burden imposed by the expansion of milling facilities.

Meat production, particularly poultry, is increasing rapidly in Japan and the European Economic Community where modern efficient methods have been introduced. This development depresses the opportunity for exporting poultry and other meats into these important trade areas, but it offers an increasing opportunity to sell feeds. Upgrading of wheat millfeeds through utilization research will increase our export markets.

USDA AND COOPERATIVE PROGRAM

Research at Albany, California, on utilization of wheat seeks to develop new processes to convert milling byproducts into higher value feeds and to modify whole wheat so that it is more economical for use as a feed grain. Research on barley is also conducted.

The Federal program of research in this area totals 1.9 scientist man-years. Research is conducted on technology--process and product development.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 0.6 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Technology--Process and Product Development

1. Enhancing Nutritive Value and Biological Activity of Cereal Fractions for Animal Feeds. We are conducting studies to develop processing treatments for wheat and barley fractions which will improve the nutritive value and biological activity of these fractions for animal feeds. Since samples of bran mash before and after pelleting show only slightly different chemical composition but significantly different metabolizable energy values, we are trying to establish which component has changed enough to upgrade the pelleted material. In vitro tests with popped wheat and barley indicate increased digestibility of processed material. By building a 1/2 ton per hour cereal popping machine, we can now process enough grain for animal feeding tests. Popped, rolled grains show promise in making high-molasses rations easier to handle.

The lipid and fatty acid contents of seven representative wheats and their derived millfeeds were determined. Also, several Pacific Northwest wheats and millfeeds were analyzed to relate nutritional variability to composition.

WHEAT UTILIZATION - INDUSTRIAL PRODUCTS
Northern Utilization Research and Development Division, ARS

Problem. Although the principal use of wheat is as food, over 200 million pounds of wheat starch and flour was consumed by industry in 1965. Loss of this market would detract from the economic value of wheat as a crop. As a food grain, wheat commands a price that is generally unfavorable to its utilization as an industrial raw material. However, in certain areas, notably the Pacific Northwest where corn is not grown, wheat is cheaper than either corn or sorghum. Furthermore, new high-yielding strains of wheat especially suited for this area are being developed. There are many paper mills in this area, and the need for technology to use starch and flour produced there has materialized. Much of the starch now used comes from imported tapioca.

Other possibilities for economic and noncompetitive industrial outlets for wheat are based on use of whole ground wheat and millfeeds, including wheat bran, and on exploitation of the properties of wheat gluten protein, which has unique properties not possessed by other cereal proteins.

Not only paper and paper products, but also coatings, adhesives, thickeners, and plastics offer excellent opportunities for industrial products derived from wheat. A more detailed discussion of industrial outlets for cereal starches and flours is given in Area No. 1, Corn Utilization - Industrial Products.

To achieve the objective, research is needed to learn how wheat flour, starch, and milling fractions can best be modified to provide new and improved properties such as water resistance, dispersibility, paste viscosity, tack, and adhesive bond strength. The possibilities of achieving some of these improvements by modification of the gluten component of flour should be investigated. Conditions must be established for optimum use of industrially promising products now under study such as acid- and enzyme-modified flours and xanthated bran and millfeeds. Basic research should provide leads to other products and processes for future development.

USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing, long-range program of research involving analytical, organic, and physical chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic, applied, and developmental studies on the composition of wheat, on characterization and properties of the components, and on their chemical and microbiological conversion to useful industrial products.

The Federal scientific effort for research on industrial utilization of wheat totals 52.3 scientist man-years. Of this number, 5.4 are devoted to chemical composition, physical properties and structure; 18.5 to chemical and physical investigations to improve products; 16.5 to microbiology and fermentation; and 11.9 to technology--process and product development.

Research at Peoria, Illinois, on chemical composition, physical properties and structure (4.0 scientist man-years) involves study of wheat flour, starch, and the component proteins of wheat gluten. Research on wheat starch is integrated with that on corn and sorghum starches. The work on wheat includes study of the microscopic and ultrastructure of wheat grains and flours and of changes induced by various treatments. During the year, studies on the rheological properties of starch were initiated. Contract research at the Purdue Research Foundation, Lafayette, Indiana, for studies on alkaline desulfurization of wheat gluten proteins has been completed. Grants (1.4 scientist man-years) are in effect at Marquette University, Milwaukee, Wisconsin, for basic studies on intermediates involved in forming glycoprotein linkages; at Iowa State University, Ames, Iowa, for basic research* on heat, mass, and momentum transport of cereal starches and flours; at Purdue Research Foundation, Lafayette, Indiana, for research* on the effects of disulfide bond cleavage on the structure of corn and wheat endosperm proteins; and at the State University of New York, Syracuse, New York, for investigations of starch fine structure.

Research at Peoria, Illinois, on chemical and physical investigations to improve products (11.9 scientist man-years) includes study of the chemical reactions of wheat starch, flour, protein and milling fractions with the objective of discovering new chemical products and processes having potential for industrial use. Research on wheat starch is integrated with that on corn starch. During the year, studies on starch-based plastifoams were completed and research on related noncellular plastics was initiated. Research contracts (3.2 scientist man-years) are in effect with the Arizona Agricultural Experiment Station, University of Arizona, Tucson, Arizona, for basic studies* on the reaction of acetylene with methyl glucoside; with the University of Akron, Akron, Ohio, for evaluation of starch and starch derivatives as reinforcing agents for natural and synthetic rubber; with Southern Illinois University, Carbondale, Illinois, for investigations* on synthesis of maltooligosaccharides; with the Institute of Paper Chemistry, Appleton, Wisconsin, for investigation* of physical chemical factors affecting retention and effectiveness of starch xanthates and xanthides in paper; with General Mills, Central Research Laboratories, Minneapolis, Minnesota, for studies on the development of cereal proteins having utility as flotation and flocculating agents; and with IIT Research Institute, Chicago, Illinois, on preparation, characterization, and chemical modification of polypeptides derived from wheat gluten. Contract research was completed by The Johns

*Work covers more than one commodity; only effort allocated to wheat is included in total.

Hopkins University, Baltimore, Maryland, for basic research on the reactions of starch in fluid dynamic media, and with Stanford Research Institute, Menlo Park, California, for research on graft copolymers of cereal starches with vinyl-type monomers. Grants (3.4 scientist man-years*) are in effect at Ohio State University Research Foundation, Columbus, Ohio, for basic research on the reaction of vinyl ethers with carbohydrates; at Ohio State University, Columbus, Ohio, for basic investigations of unsaturated and sulfur-containing carbohydrates and of the amination of starch; at Purdue Research Foundation, Lafayette, Indiana, for studies on sugars containing carbon-bound nitrogen, phosphorus and sulfur; at the University of Pittsburgh, Pittsburgh, Pennsylvania, for studies on dielectric activation of starch; at the University of Arizona, Tucson, Arizona, for basic research on the reaction of starch with diepoxides; at Southern Illinois University, Carbondale, Illinois, for studies on the alcoholysis of carbohydrate esters; and at the University of Chicago, Chicago, Illinois, for studies of reactions and transformations of serine in proteins and peptides.

Research on microbiology and fermentation conducted at Peoria, Illinois, (13.1 scientist man-years) includes studies on the use of microorganisms to convert cereal-based media to industrially useful products such as chemicals, enzymes, polymers, and biological insecticides. This research is integrated with similar studies based on corn. A large collection of pure cultures of industrially and agriculturally important microorganisms is maintained. The Pioneering Laboratory for Microbiological Chemistry conducts research on microbiological reactions and products. Investigations on biological insecticides for Japanese beetle and on other insect control agents is cooperative with Entomology Research Division and Plant Pest Control Division. Research on plant antibiotics involves cooperation with Crops Research Division. Research contracts (.9 scientist man-year*) are in effect at Michigan State University, East Lansing, Michigan, for basic research on enzyme activity in sporulation; at the University of Minnesota, St. Paul, Minnesota, for fundamental studies on the transfer of genetic determinants of sporulation from one microorganism to another; at Baylor University, Houston, Texas, for investigation of morphological changes involved in sporulation; at the American Type Culture Collection, Rockville, Maryland, for studies on preservation of certain microorganisms for which lyophilization is ineffective; and at Michigan State University, East Lansing, Michigan, for investigation of the biochemical properties of variant cultures of Bacillus popilliae. Contract research at the Kansas State University, Manhattan, Kansas, for investigation of stabilization of vegetative cells of the pathogenic organisms has been completed. Grants (2.5 scientist man-years*) are in effect at Cornell University, Ithaca, New York, for fundamental studies on biphasic fermentation; at Kansas State University, Manhattan, Kansas, for investigations on separation of enzymes and proteins by disc electrophoresis; at Iowa State University, Ames, Iowa,

*Work covers more than one commodity; only effort allocated to wheat is included in total.

for investigation on bacterial amylases and their action patterns; at the University of Wisconsin, Madison, Wisconsin, for studies on the fine structure of polysaccharide B-1973; at the University of Arkansas, Fayetteville, Arkansas, for investigation of the mechanism of enzymatic hydrolysis of starch; at the University of Nebraska, Lincoln, Nebraska, for structural studies of fungal glucohydrolases; at Baylor University, Houston, Texas, for cytology of ascospore formation in yeasts; at the University of Minnesota, Minneapolis, Minnesota, for studies of cellular differentiation and physiology of selected molds; at East Texas State University, Commerce, Texas, for determinations of branching in polysaccharides; and at Indiana State University, Terre Haute, Indiana, for surveys of gum-producing microorganisms. During the year, grant research was completed by Nebraska Agricultural Experiment Station, University of Nebraska, Lincoln, Nebraska, for investigations on the nature of amylase enzymes.

Research conducted at Peoria, Illinois, on technology--process and product development (6.4 scientist man-years) is concerned with detailed study and evaluation of wheat-derived products having definite potential for industrial utilization and of processes for making them. Also, studies are conducted on modified techniques for milling and fractionating wheat to obtain improved materials for industrial and other purposes. During the year, milling research was redirected to emphasize discovery and evaluation of new and unconventional approaches. Research involving chemical modification of wheat starch is integrated with that on corn starch. Research contracts (5.5 scientist man-years) are in effect with Stanford Research Institute, Menlo Park, California, for process development* of selected starch graft copolymers; with Western Michigan University, Kalamazoo, Michigan, for evaluation* of modified cyanoethylated starches for applications in paper; with Battelle Memorial Institute, Columbus, Ohio, for development of optimal processes for incorporating wheat-derived xanthides into paper products, and for studies* on starch derivatives for use as colloids in water-emulsion paints; with Archer Daniels Midland Company, Minneapolis, Minnesota, for investigations* on use of starch glycosides in coatings and plastics; and with the Brown Company, Berlin, New Hampshire, for evaluating acid-modified flour as a paper size. During the year, contract research on starch and other cereal grain xanthides was completed by Battelle Memorial Institute, Columbus, Ohio.

The Department also sponsors research on cereal starches conducted by foreign institutions under grants of PL 480 funds.** Research on chemical composition and physical properties involves grants to the University of London, London, England, for research on debranching enzymes and their use in studying the fine structure of starch components (5 years, 1963-1968);

*Work covers more than one commodity; only effort allocated to wheat is included in total.

**Effort prorated among corn, wheat, and grain sorghum.

and to the University of Osaka Prefecture, Sakai, Japan, for development of an analytical method for carbonyl groups in carbohydrates (4 years, 1964-1968). During the year, research on glucopyranose rings in starches and dextrans was completed at the "Giuliana Ronzoni" Scientific Institute for Chemistry and Biochemistry, Milan, Italy.

Research on chemical and physical investigations to improve products involves grants to Hebrew University, Jerusalem, Israel, for studies on starch vinyl and epoxide graft copolymers (4 years, 1963-1967); to Ahmedabad Textile Industry's Research Association, Ahmedabad, India, for research on starch-gum copolymers prepared by codextrinization (5 years, 1963-1968), and for studies on preparation and characterization of hydroxy-ethyl ethers of cereal starches (5 years, 1965-1970); to Slovenian Academy of Sciences and Arts, Ljubljana, Yugoslavia, for studies on modification of starch by moisture and temperature treatments (5 years, 1964-1969); to Plastics Research Institute TNO, Delft, The Netherlands, for research on preparation of metal alkoxides of starch for use as intermediates in synthesis (5 years, 1964-1969); to University of Edinburgh, Edinburgh, Scotland, for studies on the mechanism and structural changes involved in thermal, acid, and alkaline degradation of starches (5 years, 1964-1969); to the Institute for Fibres and Forest Products, Jerusalem, Israel, for studies on the mechanism and products of mild oxidation of starch (5 years, 1963-1968); and to the University of Graz, Graz, Austria, for rheological studies on aqueous dispersions of modified cereal starches and paper coating formulations containing starch-based adhesives (3 years, 1966-1969). During the year, research was completed on phosphorus- and sulfur-containing cationic starches at the National Institute of Technology, Rio de Janeiro, Brazil.

Research on microbiology and fermentation involves grants to the University of Allahabad, Allahabad, India, for studies on survival of lyophilized microorganisms (5 years, 1962-1967); to Central Drug Research Institute, Lucknow, India, for studies on aerobic actinomycetes in India to find new accessions for the ARS Culture Collection (5 years, 1965-1970); to the University of Liege, Liege, Belgium, for research to find lytic enzymes of microbial origin (5 years, 1964-1969); to the University of Lodz, Lodz, Poland, for research on the fermentative production of itatartaric acid (5 years, 1963-1968); to the University of Tokyo, Tokyo, Japan, for research on the fermentative production of D-tartaric acid (5 years, 1964-1969) and of mevalonic acid (3 years, 1965-1968); to the National Sugar Institute, Kanpur, India, for research on isolation of natural polysaccharide gums (3 years, 1965-1968); and to the National Institute of Agronomic Investigations, Madrid, Spain, for study and collection of aerobic species of actinomycetes (4 years, 1965-1969). During the year, research was completed on collection of new Mucorales species at the University of Allahabad, Allahabad, India; on investigations of sugar phosphate derivatives in molds at the University of Newcastle upon Tyne (formerly University of Durham), Newcastle upon Tyne, England; and on studies on the preparation and characterization of dextran derivatives at the University of Rome, Rome, Italy.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of .6 scientist man-year is devoted to research on industrial and feed uses of wheat.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition, Physical Properties and Structure

1. Characterization of wheat gluten proteins. Studies on the structure of wheat proteins resulted in isolation of one pure α -gliadin, three other α -gliadins and two β -gliadins in nearly pure condition by separation of whole gliadin on sulfoethyl cellulose and Sephadex. Larger quantities of γ_1 , γ_2 , and γ_3 -gliadins were also prepared. A comparative chromatographic and electrophoretic study of gliadin proteins from 10 wheat varieties representing four classes of wheat showed that proteins from varieties within the same class were similar, although not identical. Differences between classes were substantially greater. Two HRW wheats that have different baking properties showed only small differences in gliadin protein content. Each variety analyzed contained a gliadin component comparable to the γ_1 -gliadin of Ponca wheat. These γ_1 -gliadins have nearly identical amino acid compositions. Studies on gel-permeation chromatography of glutenin, cyanoethyl glutenin and gliadin in 8 M urea on polyacrylamide gel showed that reduced and alkylated glutenin proteins behave as particles that have apparent molecular weights near 100,000 and 40,000 in strongly deaggregating solvent.

In studies on physical chemistry of wheat gluten, it was found that when gliadin was freed of its high-molecular-weight component, the remainder showed no drop in viscosity accompanying cleavage of disulfide bonds. The conclusion is that the high-molecular-weight component contains intermolecular disulfide bonds, whereas the low-molecular-weight material contains only intramolecular disulfide bonds. Evidence was obtained that the slow secondary increase in viscosity observed after cleavage of disulfide bonds of gluten and gliadin in ethanol-acetic acid solution is caused by aggregation of unfolded peptide chains. No such increase was observed in the presence of 8 M urea. The optical rotatory dispersions of glutenin and gliadin in trifluoroethanol (helix-forming solvent) and in hexafluoroacetone sesquihydrate (random-coil forming solvent) were studied. Glutenin has 36 percent helix and gliadin has 43 percent helix in trifluoroethanol. When glutenin in trifluoroethanol was dialyzed against 0.01 N HAc, the amount of helix became 14 percent, which is the same as for glutenin in 0.01 N HAc. Helix content of glutenin and gliadin in the sesquihydrate is reduced to 11-12 percent. Optical rotatory dispersion results indicate the possibility of substantially changing the conformations of glutenin and gliadin by the proper choice of solvents.

2. Chemistry of glycoprotein linkages. Under a grant to Marquette University, glycoprotein investigations have now resulted in the synthesis of an

O-glucosaminide of 4-hydroxyproline. Unlike the earlier synthesized serine and threonine analogs, the new glucosaminide was stable to alkali. Five new O-glycosides of hydroxyamino acids have now been synthesized and characterized. Determination of the stability of these compounds toward hydrolytic conditions and solvents has given information on the stability of glycosidic linkages in glycoproteins.

3. Microscopic and ultrastructure of wheat grain. Research on microscopic and ultrastructure of wheat grain and on changes induced therein by various treatments is relevant to industrial utilization of wheat. Results are reported under "Wheat Utilization - Food," subheading A-1.

4. NMR studies. Nuclear magnetic resonance techniques are employed in studies relevant to industrial utilization of wheat. Results are reported in "Corn Utilization - Industrial Products," subheading A-3.

B. Chemical and Physical Investigations to Improve Products

1. Chemical modification of wheat gluten. Studies on chemical modification of reduced wheat proteins showed that sulfhydryl groups could be selectively modified by reaction with acrylonitrile, acrylamide or methyl acrylate. A new program for computer processing of amino acid analysis data has been successfully written and is being utilized. Sodium hydride in DMSO was shown to be a good reducing system for protein disulfide bonds. Results to date indicate that reduction proceeds without peptide cleavage or desulfurization. Decrease in lysine residues in bovine serum albumin and whole gluten proteins treated with an excess of acrylonitrile appears to follow pseudo-first-order kinetics.

2. Polypeptide derivatives. In studies under a contract to IIT Research Institute on the chemical modification of cereal polypeptides, it was found that films and fibers from epoxidized and ethyleneimine-treated gluten hydrolyzates had low tensile strengths. However, these materials showed excellent adherence to metal surfaces. A transparent water-soluble film having good tensile strength was obtained from ethyleneimine-treated hydrolyzate to which neutralized hydrolyzate had been added. Derivatives of whole gluten or of gluten hydrolyzates have been prepared and evaluated as adhesives and plastics. Polymerization of ethylene oxide in gluten hydrolyzate was shown to proceed via reaction with free amino groups. Grafting of polyoxyethylene chains to wheat gluten hydrolysis products gave materials having lower solution viscosities and sedimentation coefficients than did the untreated polypeptides. When the modified and original polypeptide fractions were subjected to gel filtration on Sephadex G-25, the original polypeptide was completely excluded from gel matrix. The modified protein contained a large fraction that was retarded. It was concluded that some degradation of polypeptide occurs and some polyethylene oxide homopolymer forms during the modification reaction. Tests of the polyethylene oxide-modified gluten hydrolyzate as a plasticizing agent for gluten indicated that films made from equal amounts of gluten and the copolymer were quite flexible.

3. Studies on wheat starch. Chemical and physical investigations on wheat starch are integrated with similar research on corn starch reported under "Corn Utilization - Industrial Products," subheading B.

C. Microbiology and Fermentation

Research on microbiological and fermentative processes for converting wheat starch or flour to industrial products is integrated with similar studies on corn. Results are reported under "Corn Utilization - Industrial Products," subheading C.

D. Technology--Process and Product Development

1. Acid-modified flour (AMF). Contract research involving experimental work on acid-modified flour (AMF) as a surface-sizing agent for paper has been completed by the Brown Company. Results show that strength and surface properties of paper sized with AMF and with commercial reference starch were similar. Protein content of the size paste remaining after 80 percent of the paste had been consumed was 14 percent, as compared to an initial value of 8 percent. Operating conditions and product properties were not adversely affected by this degree of protein buildup.

2. Other developmental research. Development of products and processes involving wheat starch is integrated with related work on corn starch. Results are given under "Corn Utilization - Industrial Utilization," subheading D.

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GRAIN SORGHUM UTILIZATION - FOOD
Northern Utilization Research and Development Division, ARS

Problem. An estimated 4 million bushels of grain sorghum are utilized annually in products for human consumption. This sorghum includes some special varieties such as white and waxy sorghums. Sorghum starch and derived glucose and glucose sirup are used in foods, and sorghum grits are used in fermented beverages. Although this outlet is at present quite limited, the growing importance of grain sorghum as a cash crop in the Southwest indicates that opportunities for increasing food use of sorghum should not be overlooked. Since grain sorghum is a staple food in many parts of Asia and Africa, a further consideration is the development of food products that could contribute to alleviation of dietary deficiencies in many developing countries.

To achieve the objective, more information on the composition of grain sorghum is needed. For example, some varieties contain pigments that can discolor milled products and that may contribute to undesired flavors. Questions have been raised concerning the digestibility and nutritive value of sorghum protein that reveal the need for better data on amino acid composition and on minor constituents.

Milling innovations, such as tangential abrasion, make possible conversion of about 20 percent of the sorghum kernel to a flour containing 25 percent protein. This and other possible approaches to new food products should be evaluated.

It has recently been discovered that certain oilseeds and cereal grains, including sorghum, are subject to infection by molds that can produce toxic products. To provide safe food products, as well as to minimize economic losses, research is needed on the detection of these toxins; on their quantitative analytical determination; and on development of processing techniques for their detoxification or removal from sorghum.

USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing, long-range program of research involving analytical, organic, and physical chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic, applied, and developmental studies pertinent to utilization of grain sorghum in food.

The Federal scientific effort for research on food utilization of grain sorghum totals 6.4 scientist man-years. Of this number, 2.6 are devoted to chemical composition and physical properties, .3 to microbiology and toxicology, and 3.5 to technology--process and product development.

Research at Peoria, Illinois, on chemical composition and physical properties (2.4 scientist man-years) involves studies on properties of grain sorghum proteins. Contract research is in effect with Kansas State University, Manhattan, Kansas, for investigations on the composition, processing, and feeding value of hybrid grain sorghum. A portion of this effort (.2 scientist man-year) is allocated to research on food uses of grain sorghum.

Research at Peoria, Illinois, on microbiology and toxicology (.2 scientist man-year) is devoted to studies on the production of mycotoxins by Aspergillus flavus and other molds. The work also includes a survey of the incidence of aflatoxin in commercial samples of various grains. A research contract in effect with the Agricultural Experiment Station, South Dakota State University, Brookings, South Dakota, provides for a survey of various species of Aspergilli to find and identify those producing toxic metabolites. A portion of this effort (.1 scientist man-year) is allocated to research on food uses of grain sorghum.

Research conducted at Peoria, Illinois, on technology--process and product development (3.5 scientist man-years) is devoted to the development of new and improved processing techniques to obtain nutritious food products.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 2.0 scientist man-years is devoted to research on food uses of grain sorghum.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Nutritional quality of grain sorghum. Contract studies on composition, processing, and feeding value of hybrid grain sorghums are important to food utilization of sorghum. Results are reported under "Grain Sorghum Utilization - Feed," subheading A-1.

B. Microbiology and Toxicology

1. Aflatoxin investigations. Studies on toxins produced by molds are important to utilization of grain sorghum in foods. Results are reported under "Corn Utilization - Feed," subheading B-1.

Preliminary studies on the performance of a variety of machines as they are applied to the dry dehulling and degermination of grain sorghum resulted in recoveries of +20 grits of 68-75 percent, with fat contents of these grits ranging from 0.4 to 0.8 percent. Best overall results were obtained from the solid rotor machine developed in the Engineering Laboratory at NU. However, all treatments--which included impaction, pearling plus impaction, dehulling in a rice huller plus impaction, and the use of a brush device--produced grits which were somewhat comparable to commercial sorghum brewers'

grits. A range of conditions was established for the partial gelatinization on heated rolls of grain sorghum flour and grits to produce products with different viscosity and other properties. This study revealed that the moisture content of the flour or grits was the most critical factor in effecting different degrees of gelatinization, with the temperature next. At higher moisture levels the temperature effect was more pronounced, while the roll speed played a lesser role. Particle size of the flour or grits did not appear to have a great effect under any conditions of gelatinization tested. Alkali dehulling was applied successfully to grain sorghum, although a discoloration remained at the tip cap of each kernel after treatment. Alkali requirements are considerably reduced for sorghum as compared to wheat.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None.

GRAIN SORGHUM UTILIZATION - FEED

Northern Utilization Research and Development Division, ARS

Problem. The principal domestic use of grain sorghum produced in the U. S. is as feed for animals. The record 655-million-bushel crop in 1965 reveals the growing importance of this grain. About 80 percent of the crop is grown in Texas, Kansas, and Nebraska.

Problems are encountered in the use of grain sorghum in feeds which, if solved, could increase utilization and economic value of this crop to farmers and to the feed industry. The major need is for more and better information on the protein content and amino acid composition of various varieties of grain sorghum as related to biological feeding value. Minor constituents having physiological activity also require more adequate study. For example, certain phenolic pigments may impart bitterness and thereby reduce palatability. Carotenoid pigments, which in part are precursors for Vitamin A, are valuable in poultry rations for imparting yellow color to egg yolks and to the skin of fryers and broilers. In addition to such compositional studies, processing investigations are needed to provide ways for preserving desired and removing undesired components. Sorghum is included in the group of cereal grains and oilseeds recently recognized to be subject to infection by molds capable of producing toxic products. To provide safe feed products and to minimize economic losses, research is needed on the detection of these toxins; on their quantitative analytical determination; and on development of processing techniques for their detoxification or removal from grain sorghum.

USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing, long-range program of research involving analytical, organic, and physical chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic, applied, and developmental studies pertinent to utilization of grain sorghum in feed.

The Federal scientific effort for research on utilization of grain sorghum in feed totals 1.0 scientist man-year, of which .7 is devoted to chemical composition and physical properties and .3 to microbiology and toxicology.

Research on chemical composition and physical properties involves a research contract in effect with Kansas State University, Manhattan, Kansas, for investigations on the composition, processing, and feeding value of hybrid grain sorghums. A portion of this effort (.7 scientist man-year) is allocated to research on feed uses of grain sorghum.

Research at Peoria, Illinois, on microbiology and toxicology (.2 scientist man-year) is concerned with studies on the production of mycotoxins by

Aspergillus flavus and related molds. A research contract (.1 scientist man-year*) is in effect with the Agricultural Experiment Station, South Dakota State University, Brookings, South Dakota, for survey of the genus Aspergillus to find and identify species producing toxic metabolites. During the reporting period, research was completed at A. D. Little, Inc., Cambridge, Massachusetts, for studies on stabilization of fermentative β -carotene, and with Consolidated Laboratories, Inc., Chicago Heights, Illinois, for research on the use of antimetabolites to facilitate selection of higher yielding strains of microorganisms producing β -carotene.

The Department also sponsors research in this area conducted under grants of PL 480 funds. Research on chemical composition and physical properties involves a grant to the Indian Institute of Science, Bangalore, India, for research on separation of grain sorghum proteins (5 years, 1963-1968).

Research on microbiology and toxicology involves a grant to the Agricultural University, Poznan, Poland, for studies to increase the yield of β -carotene produced by fermentation of cereal grains (4 years, 1966-1970). Effort on this project is prorated among corn, wheat, and sorghum.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of .3 scientist man-year is devoted to research on industrial and feed uses of grain sorghum.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Nutritional quality of grain sorghum. In studies on the nutritional quality of sorghum proteins, conducted under a contract with Kansas State University, eight diets, each based on a different sample of 1965 crop sorghum, were fed to chicks over a period of 4 weeks. Each diet contained 15 percent of protein and consisted of 78.5 percent sorghum, 10 percent soybean meal, and small amounts of other needed ingredients. Compositional differences among the sorghum samples were disappointingly low because of an unusual growing season. Weight gains for the chicks were not significantly altered by different sorghum hybrids; by location where sorghum was grown; or by nitrogen fertilization or irrigation of growing sorghum. Addition of pure lysine to these diets significantly increased weight gain, but no significant change occurred with methionine. Therefore, methionine may not be the first limiting amino acid as thought previously. Feeding experiments are currently underway using sorghum from the 1966 crop. This crop is similar to the 1965 crop in that variety, location, fertilizer level, and irrigation appear to have had minimum effect on protein content.

*Work covers more than one commodity; only effort allocated to grain sorghum is included in total.

2. Studies on sorghum proteins. Under a PL 480 grant at the Indian Institute of Science, lysine determinations have been completed on 44 varieties of sorghum of world-wide origin and five Indian varieties. With only one exception, lysine content of protein showed a negative correlation with protein content. Complete amino acid analyses by ion exchange chromatographic procedures for six genetic varieties and three hybrid varieties of sorghum seed representing high and low protein levels indicate that prolamine and glutelin are the major protein fractions and that variations in the total amount of protein are primarily attributable to differences in the prolamine content. Amino acid composition studies of the various protein fractions are continuing.

B. Microbiology and Toxicology

1. Aflatoxin investigations. Studies on toxins produced by molds are important to utilization of grain sorghums in feeds. Results are reported under "Corn Utilization - Feed," subheading B-1.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None.

GRAIN SORGHUM UTILIZATION - INDUSTRIAL PRODUCTS
Northern Utilization Research and Development Division, ARS

Problem. The growing importance of grain sorghum as a competitive crop is revealed by the record 655-million-bushel crop in 1965. About 80 percent of the grain sorghum crop is grown in Texas, Kansas, and Nebraska. Sorghum starch and flour find industrial usage where freight transportation advantages exist. Currently an estimated 6 million bushels of sorghum are milled for products consumed mainly by the paper and gypsum board industries. To maintain this market against competition from synthetics and to take advantage of opportunities that exist in economically favorable geographic areas for increased industrial utilization of sorghum, technology suited to the specific characteristics of this grain and its milled products must be developed.

Research on sorghum starch is integrated with that on corn starch. A more detailed discussion of promising industrial outlets and of the pertinent research required is given under Area 1, Corn Utilization - Industrial Products. Because grain sorghum has a round kernel in contrast to the odd-shaped kernel of corn, it lends itself to dry milling innovations not possible with corn. Milling improvements, together with the possible advantages of air classification of sorghum flour, offer prospects for increasing industrial utilization by making processing economics more attractive and by providing products with superior properties.

USDA AND COOPERATIVE PROGRAMS

The Department conducts a continuing, long-range program of research involving analytical, organic, and physical chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic, applied, and developmental studies on the composition of grain sorghum, on characterization and properties of the components, and on their chemical and microbiological conversion to useful industrial products.

The Federal scientific effort for research on industrial utilization of grain sorghum totals 9.6 scientist man-years. Of this number, .5 is devoted to chemical composition, physical properties and structure; 3.1 to chemical and physical investigations to improve products; 4.1 to microbiology and fermentation; and 1.9 to technology--process and product development.

Research at Peoria, Illinois, on chemical composition, physical properties and structure (.3 scientist man-year) involves study of applications of nuclear magnetic resonance spectroscopy to grain components and is integrated with related research on corn. During the year, studies on the rheological properties of starch were initiated. Contract research was completed by Indiana University Foundation, Bloomington, Indiana, for studies on the isolation and characterization of phenolic pigments of

grain sorghum. Grants (.2 scientist man-year*) are in effect with Iowa State University, Ames, Iowa, for basic research on heat, mass, and momentum transport of cereal starches and flours; and with the State University of New York, Syracuse, New York, for investigations of starch fine structure.

Research at Peoria, Illinois, on chemical and physical investigations to improve products (1.9 scientist man-years) is integrated with research on corn starch and is directed to wide-ranging study of the chemical reactions of starch with the objective of discovering new chemical products and processes having potential for industrial use. During the year, studies on starch-based plastifoams were completed and research on related noncellular plastics was initiated. Research contracts (.5 scientist man-year*) are in effect with the Arizona Agricultural Experiment Station, University of Arizona, Tucson, Arizona, for basic studies on the reaction of acetylene with methyl glucoside; with the University of Akron, Akron, Ohio, for evaluation of starch and starch derivatives as reinforcing agents for natural and synthetic rubber; with Southern Illinois University, Carbondale, Illinois, for investigations on synthesis of maltooligosaccharides; with the Institute of Paper Chemistry, Appleton, Wisconsin, for investigation of physical chemical factors affecting retention and effectiveness of starch xanthates and xanthides in paper; and with General Mills, Central Research Laboratories, Minneapolis, Minnesota, for studies on the development of cereal proteins having utility as flotation and flocculating agents. Contract research was completed by The Johns Hopkins University, Baltimore, Maryland, for basic research on the reactions of starch in fluid dynamic media, and with Stanford Research Institute, Menlo Park, California, for research on graft copolymers of cereal starches with vinyl-type monomers. Grants (.7 scientist man-year*) are in effect with Ohio State University Research Foundation, Columbus, Ohio, for basic research on the reaction of vinyl ethers with carbohydrates; with Ohio State University, Columbus, Ohio, for basic investigations of unsaturated and sulfur-containing carbohydrates and of the amination of starch; with Purdue Research Foundation, Lafayette, Indiana, for studies on sugars containing carbon-bound nitrogen, phosphorus, and sulfur; with the University of Pittsburgh, Pittsburgh, Pennsylvania, for studies on dielectric activation of starch; with the University of Arizona, Tucson, Arizona, for basic research on the reaction of starch with diepoxides; and with Southern Illinois University, Carbondale, Illinois, for studies on the alcoholysis of carbohydrate esters.

Research on microbiology and fermentation conducted at Peoria, Illinois, (3.3 scientist man-years) includes studies on the use of microorganisms to convert cereal-based media to industrially useful products such as chemicals, enzymes, polymers, and biological insecticides. This research is integrated with similar studies based on corn. A large collection of pure cultures of industrially and agriculturally important microorganisms is

*Work covers more than one commodity; only effort allocated to grain sorghum is included in total.

maintained. The Pioneering Laboratory for Microbiological Chemistry conducts research on microbiological reactions and products. Investigations on biological insecticides for Japanese beetle and on other insect control agents is cooperative with Entomology Research Division and Plant Pest Control Division. Research on plant antibiotics involves cooperation with Crops Research Division. Research contracts (.2 scientist man-year*) are in effect at Michigan State University, East Lansing, Michigan, for basic research on enzyme activity in sporulation; at the University of Minnesota, St. Paul, Minnesota, for fundamental studies on the transfer of genetic determinants of sporulation from one microorganism to another; at Baylor University, Houston, Texas, for investigation of morphological changes involved in sporulation; at the American Type Culture Collection, Rockville, Maryland, for studies on preservation of certain microorganisms for which lyophilization is ineffective; and at Michigan State University, East Lansing, Michigan, for investigation of the biochemical properties of variant cultures of Bacillus popilliae. Contract research at the Kansas State University, Manhattan, Kansas, for investigation of stabilization of vegetative cells of the pathogenic organisms has been completed. Grants (.6 scientist man-year*) are in effect at Cornell University, Ithaca, New York, for fundamental studies on biphasic fermentation; at Kansas State University, Manhattan, Kansas, for investigations on separation of enzymes and proteins by disc electrophoresis; at Iowa State University, Ames, Iowa, for investigation of bacterial amylases and their action patterns; at the University of Wisconsin, Madison, Wisconsin, for studies on the fine structure of polysaccharide B-1973; at the University of Arkansas, Fayetteville, Arkansas, for investigation of the mechanism of enzymatic hydrolysis of starch; at the University of Nebraska, Lincoln, Nebraska, for structural studies of fungal glucosylhydrolases; at Baylor University, Houston, Texas, for cytology of ascospore formation in yeasts; at the University of Minnesota, Minneapolis, Minnesota, for studies on cellular differentiation and physiology of selected molds; at East Texas State University, Commerce, Texas, for determinations of branching in polysaccharides; and at Indiana State University, Terre Haute, Indiana, for surveys of gum-producing microorganisms. During the year, grant research was completed by Nebraska Agricultural Experiment Station, University of Nebraska, Lincoln, Nebraska, for investigations on the nature of amylase enzymes.

Research conducted at Peoria, Illinois, on technology--process and product development (1.4 scientist man-years) is concerned with detailed study and evaluation of starch derivatives having definite potential for industrial utilization and of processes for making them. The work is integrated with similar studies on corn starch derivatives. Research contracts (.5 scientist man-year*) are in effect at Stanford Research Institute, Menlo Park, California, for process development of selected starch graft copolymers; at Western Michigan University, Kalamazoo, Michigan, for evaluation of

*Work covers more than one commodity; only effort allocated to grain sorghum is included in total.

modified cyanoethylated starches for applications in paper; at Battelle Memorial Institute, Columbus, Ohio, for studies on starch derivatives for use as colloids in water-emulsion paints; and at Archer Daniels Midland Company, Minneapolis, Minnesota, for investigations on the use of starch glycosides in coatings and plastics. During the year, contract research on starch and other cereal grain xanthides was completed by Battelle Memorial Institute, Columbus, Ohio.

The Department also sponsors research on cereal starches conducted by foreign institutions under grants of PL 480 funds.^{*} Research on chemical composition, physical properties and structure involves grants to the University of London, London, England, for research on debranching enzymes and their use in studying the fine structure of starch components (5 years, 1963-1968); and to the University of Osaka Prefecture, Sakai, Japan, for development of an analytical method for carbonyl groups in carbohydrates (4 years, 1964-1968). During the year, research on glucopyranose rings in starches and dextrans was completed at the "Giuliana Ronzoni" Scientific Institute for Chemistry and Biochemistry, Milan, Italy.

Research on chemical and physical investigations to improve products involves grants to Hebrew University, Jerusalem, Israel, for studies on starch vinyl and epoxide graft copolymers (4 years, 1963-1967); to Ahmedabad Textile Industry's Research Association, Ahmedabad, India, for research on starch-gum copolymers prepared by codextrinization (5 years, 1963-1968), and for studies on preparation and characterization of hydroxyethyl ethers of cereal starches (5 years, 1965-1970); to Slovenian Academy of Sciences and Arts, Ljubljana, Yugoslavia, for studies on modification of starch by moisture and temperature treatments (5 years, 1964-1969); to Plastics Research Institute TNO, Delft, The Netherlands, for research on preparation of metal alkoxides of starch for use as intermediates in synthesis (5 years, 1964-1969); to the University of Edinburgh, Edinburgh, Scotland, for studies on the mechanism and structural changes involved in thermal, acid, and alkaline degradation of starches (5 years, 1964-1969); to the Institute for Fibres and Forest Products Research, Jerusalem, Israel, for studies on the mechanism and products of mild oxidation of starch (5 years, 1963-1968); and to the University of Graz, Graz, Austria, for rheological studies on aqueous dispersions of modified cereal starches and paper coating formulations containing starch-based adhesives (3 years, 1966-1969). During the year, research was completed on phosphorus- and sulfur-containing cationic starches at the National Institute of Technology, Rio de Janeiro, Brazil.

Research on microbiology and fermentation involves grants to the University of Allahabad, Allahabad, India, for studies on survival of lyophilized microorganisms (5 years, 1962-1967); to Central Drug Research Institute,

^{*}Effort prorated among corn, wheat, and grain sorghum.

Lucknow, India, for studies on aerobic actinomycetes in India to find new accessions for the ARS Culture Collection (5 years, 1965-1970); to the University of Liege, Liege, Belgium, for research to find lytic enzymes of microbial origin (5 years, 1964-1969); to the University of Lodz, Lodz, Poland, for research on the fermentative production of itatartaric acid (5 years, 1963-1968); to the University of Tokyo, Tokyo, Japan, for research on the fermentative production of D-tartaric acid (5 years, 1964-1969) and of mevalonic acid (3 years, 1965-1968); to the National Sugar Institute, Kanpur, India, for research on isolation of natural polysaccharide gums (3 years, 1965-1968); and to the National Institute of Agronomic Investigations, Madrid, Spain, for study and collection of aerobic species of actinomycetes (4 years, 1965-1969). During the year, research was completed on collection of new Mucorales species at the University of Allahabad, Allahabad, India; on investigations of sugar phosphate derivatives in molds at the University of Newcastle upon Tyne (formerly University of Durham), Newcastle upon Tyne, England; and on studies on the preparation and characterization of dextran derivatives at the University of Rome, Rome, Italy.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of .3 scientist man-year is devoted to research on industrial and feed uses of grain sorghum.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition, Physical Properties and Structure

1. NMR studies. Nuclear magnetic resonance techniques are employed in studies relevant to industrial utilization of grain sorghum. Results are reported under "Corn Utilization - Industrial Products," subheading A-3.

B. Chemical and Physical Investigations to Improve Products

C. Microbiology and Fermentation

D. Technology--Process and Product Development

Research in these categories is integrated with similar investigations on corn starch. Results are reported under "Corn Utilization - Industrial Products," subheadings B, C, and D.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Technology--Process and Product Development

Stringfellow, A. C., and Peplinski, A. J. 1966. Air classification of sorghum flours from varieties representing different hardnesses. Cereal Sci. Today 11(10), pp. 438-440, 445.

FORAGE UTILIZATION - FEED
Northern Utilization Research and Development Division, ARS

Problem. Tall fescue grass is grown extensively in the Southeast, in the Intermountain States, and in the Pacific Northwest as a forage crop for cattle and other domestic animals. It has excellent agronomic characteristics, producing well on marginal land and remaining green during cool weather when other grasses are dormant. The quality of staying green in the winter is a prime factor in its acceptance. Thirty-five to fifty million acres of fescue are grown for forage use in the Southeastern part of the United States alone.

Cattle grazing on pasture that is predominately tall fescue sometimes develop a disease known as "fescue foot." In severe attacks the animal first becomes lame. The peripheral portion of one or more limbs then develops necrosis, and sloughing of the hooves may occur. Occasionally the tail and ears may be affected. Animals become emaciated and frequently die. The disorder is more apt to occur during cool weather than during the summer months. However, even when conditions are not such as to produce the more dramatic symptoms, cattle sometimes perform poorly on fescue forage, a result which may be attributed to subclinical toxicity.

Pastures may become toxic after several years of freedom from toxicity. Serious outbreaks of fescue toxicity occurred during the winter 1963-64 in parts of Kentucky, Illinois, Missouri, Kansas, and Arkansas. Thousands of head were involved, with morbidity ranging from 1 percent to 99 percent of the herds. For example, 42 of 72 head of cattle became lame after 8 days on one pasture in Missouri. In these outbreaks, the toxic pastures were soil bank lands having long grass that was pastured after the advent of cold weather.

Research to determine the cause of toxicity in fescue and to identify the toxic substance(s) is needed as a basic step in developing a solution to the problem of toxic fescue.

USDA AND COOPERATIVE PROGRAMS

At the Northern Division, Peoria, Illinois, the Department has a program of limited scope that involves one organic chemist engaged in research to isolate and identify the toxic component(s) of tall fescue grass responsible for a cattle disease known as "fescue foot." This research is cooperative with the Kentucky State Experiment Station, which furnishes toxic and non-toxic fescue grass for chemical study and conducts bioassays of fractions and components isolated from fescue at the Northern Division. Liaison is maintained with the fescue breeding program of the Field Crops Research Branch, ARS, through the Agronomy Department of the University of Kentucky and with the Department's Pharmacology Laboratory at the Western Division.

The major part of the Department's research program on forages is maintained at the Western Utilization Research and Development Division, Albany, California.

The Federal program at Peoria, Illinois, totals 1.4 scientist man-years, all of which is devoted to microbiology and toxicology.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 4.5 scientist man-years is devoted to research in this area.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Microbiology and Toxicology

1. Fescue toxicity. The complete structure of γ -acetamido- $\Delta^{\alpha,\beta}$ -butenolide (I) isolated from cultures of Fusarium nivale has been established. It was found that (I) has no pronounced antibiotic activity against 14 bacteria, 3 molds, and 1 yeast. A sublethal dose for cattle of the toxic aqueous-alcoholic extract of F. nivale grown on hay lowered the tailskin temperature, but did not produce gangrene. Aqueous-alcoholic extracts of toxic fescue hay were toxic to rabbit skin even though they contained no demonstrable IR bands of (I). Compound (I), present in F. nivale cultures, is not wholly recovered in such extracts. F. nivale also produces a sesquiterpenoid, a toxin identical to (or an enantiomorph of) isovaleroloxodiacetoxyscirpenol, isolated by the University of Wisconsin from F. tricinctum. Samples of forage from a toxic fescue pasture have been gathered while the cattle were sick with fescue foot. This presents the first opportunity to examine the microbiology of field forage as it exists while the cattle are still sick.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Microbiology and Toxicology

Yates, S. G., Tookey, H. L., Ellis, J. J., and Burkhardt, H. J.¹ (¹West. Util. Res. Develop. Div., Albany, California). 1967. Toxic butenolide produced by Fusarium nivale (Fries) Cesati isolated from tall fescue (Festuca arundinacea Schreb.). Tetrahedron Lett. (7), pp. 621-625.

Keyl, A. C.,¹ Lewis, J. C.,¹ Ellis, J. J., Yates, S. G., and Tookey, H. L. (¹West. Util. Res. Develop. Div., Albany, California). 1967. Toxic fungi isolated from tall fescue. Mycopathol. Mycol. Appl. 31(3-4), pp. 327-331.

FORAGE UTILIZATION - FEED

Western Utilization Research and Development Division, ARS

Problem. The demand for livestock in the United States will increase 45% by 1975. Since forage crops constitute the major feedstuff for ruminant animals, the demand for forages will increase accordingly. In addition, there is an increasing demand for processed forages in European and Asiatic markets as well as in domestic markets. Fresh forage crops are the richest natural source of many nutrients for farm animals. Forages, however, are preserved so inefficiently by hay-making and ensiling that 10 to 50% of the dry weight and much larger fractions of the most valuable nutrients are lost before the animals eat them. Dehydration is now the only practical means of producing products of high nutritional value in a form usable in manufactured feeds and supplements. Poultry and swine producers are aware of the value of dehydrated forage, but restrict their use of it because of its high fiber and growth-inhibitor content. There is evidence that certain unidentified growth factors are lost, at least partially, during the dehydration process as presently carried out. The livestock breeder needs forage products tailored to specific animals, and the forage producer must adapt to his needs to sell.

Basic and applied utilization research are necessary to produce: (1) high-protein, low-fiber feeds rich in unidentified growth factors designed for use by non-ruminant animals; (2) fiber products which have been cheaply treated to make them easily digestible for ruminants; (3) growth-stimulating supplements for ruminants, derived from the biologically active fiber-digestion factors and growth-promoting factors in forage. New products should be adaptable to mechanical feeding. Improved uses will encourage farmers to put high-value land into forage crops.

USDA AND COOPERATIVE PROGRAMS

Current research in the Western Utilization Research and Development Division includes both basic and applied studies on all forages used or potentially usable for off-the-farm processing. The research is conducted at the Division headquarters at Albany, California; under contracts at Lincoln, Nebraska, and Tifton, Georgia; and under P.L. 480 grant programs in Israel and Italy. The mechanical separation of leaf from stem of alfalfa is being studied with financial support from the Department of Agriculture and Inspection of the State of Nebraska and the cooperation of several experiment stations and commercial processors and users of forages. Products are being evaluated at the University of Nebraska, Kansas State University, Purdue University and the Agricultural and Mechanical College of Texas. Research on increasing the digestibility of stem carbohydrates by ruminants is being done under contract at the University of Nebraska. Also under study are biologically active forage constituents (such as the guinea pig and chick-growth-promoting factors in forages and alfalfa saponins which depress chick growth), organic acids of alfalfa, non-

protein nitrogen compounds of alfalfa, and the mechanism of action of forage antioxidants. The guinea pig growth factor work is being done in cooperation with the University of California in Berkeley. Processing of forages by "wet" (juicing) methods is being investigated in cooperation with a commercial company. The effects of dehydration conditions on losses of carotene and xanthophyll are being studied.

The Federal program of research in this area totals 6.7 scientist man-years, including one scientist whose salary is provided by the Department of Agriculture and Inspection, State of Nebraska, and contract research. Research is conducted on technology--process and product development. In addition the Division sponsors, under P.L. 480, three research projects on forages.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 4.2 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Technology--Process and Product Development

1. Improved Feeds from Alfalfa and Other Forage Crops. Lipids are major contributors to the biological value of alfalfa, but they are subject to oxidative deterioration. An investigation of certain lipid constituents of alfalfa and their relationship to the autoxidation of alfalfa carotenoids has been concluded at the University of California in Berkeley. This study showed that during the first 24-hour holding period after harvesting, freshly cut alfalfa lost approximately 75% of the beta-carotene contents, 12% of the extractable lipids, 30% of the linolenic acid, and 60-75% of the galactolipids, and the free fatty acid content doubled. The holding period also decreased somewhat the effectiveness of ethoxyquin in protecting the lipid constituents. During a second 24-hour holding period the extractable lipids showed another sharp decrease. The losses of other lipid constituents were considerably smaller than those found during the first 24-hour period. These data re-emphasize the importance of keeping the time between harvest and dehydration at an absolute minimum.

Analytical procedures were developed to determine the amounts of galactolipids, beta-carotene, total extractable lipid and fatty acids in fresh lyophilized alfalfa. These methods were used in determining the lipid changes which occur in freshly cut alfalfa before and after dehydration and in stored dehydrated meal with and without added ethoxyquin. Monogalactolipid was 11-14% of the total lipids and digalactolipid was 6-7%. Unlike phosphatidyl choline and phosphatidyl ethanolamine these purified complex lipids showed no synergistic antioxidant activity in squalene or menhaden oil. Digalactolipid showed some prooxidant activity. The length of time the alfalfa was held prior to lyophilization did not grossly alter the effectiveness of ethoxyquin in protecting the lipid constituents in the dehydrated meal.

Because of their association with biological activity, phenolic compounds of alfalfa and other forages are under investigation. Characterization work has been completed on a number of previously isolated phenolic compounds. They include the novel dicoumarin, daphnoretin, from ladino clover, as well as two flavones previously unreported in nature, 7,4'-dihydroxyflavone and 7,3',4'-trihydroxyflavone. Alfalfa has been shown to contain a whole family of coumestans of which coumestrol may be considered to be the simplest member. To date, a total of eight such coumestans have been characterized. They include coumestrol, 3'-methoxycoumestrol, 4'-methoxycoumestrol, lucernol, medicagol, sativol, trifoliol, and 7-hydroxy-11,12-dimethoxycoumestan.

Studies conducted in cooperation with the Alfalfa Investigations of the Crops Research Division of the Agricultural Research Service to show the relationship of disease to buildup of phenolic compounds in forages have been completed. They demonstrated that plant diseases such as common leaf spot and rust will produce a very rapid "buildup" of a number of phenolic compounds in the forage plant. The total amount of each compound appears to increase with the severity of the attack. The compounds predominate around the locus of the infection, suggesting that the compounds may in some way be related to the protective or disease-resistance mechanism of the plant. In related work, in cooperation with Purdue University it has been found that the levels of coumestrol and other phenolics may also be under genetic control.

A limited number of tests of the anti-fungal properties of coumestans were carried out. Under the test conditions employed, no anti-fungal activity was observed. Limited tests were also carried out for insecticidal properties in cooperation with the Entomology Division of the Agricultural Research Service at Beltsville also with negative results.

Studies relating to the growth-promoting effects of coumestrol on large animals have continued in cooperation with Purdue University and American Dehydrators Association. The most recent work, in which pure crystalline coumestrol has been fed in the diet of beef cattle has not confirmed the growth responses previously obtained with cruder extracts. This suggests that other presently unidentified factors present in the crude extracts may have been the actual growth-promoting agents.

Contract research is being conducted at the University of Georgia to improve processed forages by determining the effects of unit industrial processes on the chemical composition and nutrient availability of dehydrated forage crops. Gahi millet and Coastal Bermuda grass were grown with varying fertilizer combinations with and without irrigation. Serial cuttings of the Coastal Bermuda were made at 3-1/2 week intervals. Three cuttings of millet were made in July, August and September. Analytical and stability studies are not complete. Xanthophyll utilization tests show that dehydrated millet is significantly better than Coastal Bermuda grass in promoting xanthophyll deposition in chicks. Other comparisons

showed the millet's deposition of xanthophyll was at least equal to that of alfalfa, and both were superior to corn gluten meal which ranked close to the Coastal Bermuda grass.

Contract research is being conducted at the University of Nebraska in Lincoln to increase the use of alfalfa in mixed feeds by removing or degrading lignin and thus increasing the availability of the cellulose to ruminants. A variety of treatments were evaluated for their effects on the digestibility of alfalfa stem materials. Incubation with acids had no effect but incubation with a number of basic or peroxidic compounds increased digestibility significantly, as determined by artificial rumen studies. Water content, temperature, and heating time were not critical. Digestibility increases of up to 33% were achieved with ethanolamine-water mixtures. Treatments with sodium or hydrogen peroxide gave inconsistent results. Other reagents used in the wood industry were found to be inferior to the above treatments. Removal of water-soluble constituents of the stem prior to treatment had no effect, nor was excess oxygen helpful. In a sheep experiment, rumen microorganisms made inefficient use of ethanolamine, and in vivo results correlated with "artificial rumen" tests. The results indicate that it is not necessary to completely destroy lignin in order to markedly improve cellulose digestion.

We are conducting research to develop rapid microbiological or other assay procedures that correlate with guinea pig and chick growth response to alfalfa. Microbial assay of alfalfa juice concentrate for unidentified growth factors was begun. Activity could be chromatographed into three fractions: the material not absorbed on the column, material eluted from the column with 10% ammonium hydroxide, and material eluted with hydrochloric acid. Each fraction was inactive, but by recombining the materials eluted with hydrochloric acid and ammonium hydroxide, most of the activity of the original alfalfa was accounted for. About 80% of the material eluted with hydrochloric acid was attributable to magnesium. Essentially all of the remaining activity was attributable to calcium and potassium salts. Isolation studies on the material eluted with ammonium hydroxide are now underway.

Addition of 10% dehydrated alfalfa to the diet of guinea pigs resulted in improvement in growth of up to 50 grams over a 3-week assay period. The unidentified factor(s) appears to be distinct from all known vitamins, minerals, amino acids, or other nutrients, and it appears to be organic in nature, since it is not found in the ash of alfalfa. This work is being done in cooperation with the University of California in Berkeley.

P.L. 480 funds are supporting two research projects in Israel. The Hebrew University-Hadassah Medical School in Jerusalem has begun a study to isolate and evaluate anti-estrogen components from alfalfa to guide the development of improved dehydration procedures. Research to detoxify or remove growth-depressing saponins from alfalfa feeds is being conducted at the Hebrew University in Rehovot.

The Experiment Station for Practical Agriculture in Milano, Italy, supported by P.L. 480 funds is investigating the factors effecting the variability of natural antioxidant in alfalfa to improve stabilization of dehydrated products. Chromatography of pigment-free lipid extracts produces seven fractions with reducing activity. These substances increase rapidly during the first vegetative phases. One principal component has been tentatively identified as plastohydroquinone. Activity is present in leaves but not in the stem. Several components are destroyed by dehydration; one, however, is markedly increased and remains stable for 200 days storage. A rapid preparative technique for isolation of individual components has been developed.

We are studying processing techniques which might develop forage feeds with enhanced biological activity. We have found that up to 70% of the xanthophyll in alfalfa was lost during dehydration. Losses correlated with the dehydrator outlet temperature and the moisture of the meal. Of the xanthophylls, lutein was more stable than neoxanthin or violaxanthin. A new analytical procedure for xanthophyll of alfalfa permits prediction of pigmentation of broilers and correlates with corn gluten xanthophyll analysis. Neoxanthin was detected in broiler skin. Research on non-protein nitrogen compounds of alfalfa showed that the quantity of stachydrine in alfalfa greatly exceeds that of betaine. An unknown related compound is also present. We analyzed eight alfalfa samples and their fiber residues for protein, fat, fiber, ash, pentosans, lignin, anhydrouronic acid, starch and reducing sugar. Air classification of leaf-stem was conducted in a zig-zag type separator on full production scale. Stem meal was found to be pelletable if proper conditions were used.

2. Improved Stability of Alfalfa and Other Forage Products for Export. We are conducting research to develop practical techniques for processing forages to stabilize or concentrate the valuable components of forages. The use of alfalfa in mixed feeds for poultry is based principally on its xanthophyll content. We have found that up to 70% of the xanthophyll in alfalfa can be lost during dehydration. These losses correlated with the dehydrator outlet temperature and the moisture of the meal.

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RICE UTILIZATION - FOOD
Southern Utilization Research and Development Division, ARS

Problem. The productive capacity of U. S. rice growers has increased faster than domestic and export consumption over the past decade, thus limiting the income potentially available from this major world food grain. Detailed knowledge of chemical composition and physical properties as related to processing is needed to guide milling, processing, and product development of U. S. rices so that they can better meet the quality and new product requirements needed for expanded markets. New and diverse food products that are economical to manufacture, convenient to prepare, and attractive in flavor and texture are needed to increase the total consumption of rice both domestically and abroad. Additional needs include the development of improved milling machinery and techniques, primarily to increase the yield of head rice; intensified research on deep milling to evaluate and utilize the protein flour and residual kernels produced by this technique; and research to provide greater flexibility in the industry by developing from either medium or long-grain rice new products that can be cooked to provide discrete kernels or as a gelatinous food.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program at New Orleans, Louisiana, involving biochemists and analytical chemists engaged in research on the chemical composition and physical properties of rice and its products. Research is being conducted to improve the potential of rice for new food, feed, and industrial products in relation to the physical properties and chemical composition of whole and fractionated kernels. Close cooperation is maintained, under formal memoranda of understanding, with the Louisiana, Arkansas, and Texas Rice Experiment Stations, who supply rice samples of known variety and cultural history for the experimental studies. The Rice Inspection Service, Grain Division, C&MS, New Orleans, Louisiana, cooperates by providing assistance in grading rice samples from the research investigations. Cooperation is also maintained with the Western Division.

Other research on chemical composition and physical properties is also being conducted under a P. L. 480 grant to Kyoto University, Kyoto, Japan. Scientists at this institution will study the distribution of the major proteins of rice within subcellular particles and the distribution of these particles in the cellular structure of the rice kernel to obtain basic information needed to develop new and improved rice products and methods of producing them (project duration--3 yrs.).

The Federal in-house scientific effort devoted to research in this area totals 2.0 scientific man-years, all of which are presently applied to chemical composition and physical properties.

Under P. L. 480 research there is presently one grant, also on chemical composition and physical properties.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 0.8 scientific man-year is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Investigation of the Distribution of the Proteins and Other Constituents in the Rice Kernel. Under a P. L. 480 project at Kyoto University, Kyoto, Japan, a study is underway on the distribution of the major proteins of rice within the subcellular particles, and the distribution of these particles in the cellular structure of the rice kernel. Proteinaceous subcellular particles 1 to 4 microns in diameter, of oval or spherical shape, have been revealed by electron microscopic examination of rice endosperm. These particles have been isolated in fairly pure state and in good yield by differential centrifugation in density gradient media, after mechanical or enzymatic disintegration of the endosperm cells. The isolated particles are about 60% protein, dry basis, the remainder being lipids and carbohydrates. The investigators have postulated that these particles are the protein reserve subcellular particles in the rice endosperm. Research is now underway to develop better methods for the characterization of major proteins and to compare the protein fractions of white rice with those in rice polish. Basic information gained in the investigation will be of use in developing high-protein fractions from rice for use as enriching components of foods. (UR-All-(10)-23).

Research has continued on the chemical composition and physical properties of high-protein rice flours prepared in a commercial Satake mill, a Japanese machine designed for the deep milling of rice in the manufacture of sake. Determination of levels of mineral nutrients showed that phosphorus, sulfur, potassium, calcium, and iron were considerably greater in the flours than in the original rice and residual kernels, whereas the level of copper was lower in the flours. Rice deep milled to about 6-7% weight removal had improved cooking quality. Machine variables of the Satake mill are being studied to determine optimum and economic conditions of operation with long- and medium-grain rices for the production of high-protein flours. In another phase of the research, an expanded, flavored rice snack has been prepared; it is similar to corn snacks but has a more desirable uniform tender texture. Also, a gelatinized rice flour that is soluble in cold water and is suitable as a thickening agent in mixtures with oilseed flours as a beverage or gruel appears particularly attractive for rice-eating developing countries. This research is conducted in cooperation with the Louisiana Agricultural Experiment Station. (S1 4-13, S1 4-14).

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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RICE UTILIZATION - FOOD
Western Utilization Research and Development Division, ARS

Problem. Limitations on U.S. rice acreage are being relaxed because of the increasing need for rice to export into food-short areas, particularly Southeast Asia. Polished rice is a relatively expensive source of nutrients because its protein, although high in quality, is only about 5% to 7% of the kernel, and it is almost devoid of vitamins. The need is for new and improved food products with better nutritive quality and produced at minimum increase in cost. Such products must be easy to prepare; have good texture, flavor, and appearance; and be economical to manufacture. Also needed are drastically improved milling methods to increase economic returns to growers and millers so that cost to consumers will not increase. Detailed knowledge of chemical composition and physical properties as related to processing is needed to guide the developments in milling, processing, and development of products that meet the growing export demand.

USDA AND COOPERATIVE PROGRAM

In the Western Utilization Research and Development Division, basic and applied research is conducted at Albany, California, and, by contract at Berkeley, California, on rice proteins, debranning of brown rice by lye-peeling, parboiling of brown and under-milled rice, new methods to produce quick-cooking forms having better flavor and texture, and conversion of high-protein flours into beverage products especially suitable for infant feeding overseas.

The Federal program of research in this area totals 2.3 professional man-years, assigned to investigations of technology--process and product development. In addition, the Division sponsors one research grant under P.L. 480 in Japan.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 0.8 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Technology--Process and Product Development

1. Development of New Rice Products Such as Deep Milled Rice Flour, Improved Quick-Cooking Rice and Rice of Improved Flavor Stability. We are conducting research designed to improve the color, flavor, and convenience of conventional consumer rice products. Also, we are seeking to develop new high-protein products for growing specialty markets. To do this we are studying rice proteins, particularly in relation to processing procedures or cooking properties. Determinations were made of the distribution of

proteins in typical varieties of milled rice. We found the proportions of albumin (water-soluble proteins) and globulin (proteins which are soluble in a salt solution) increased markedly from the inner to outer rice kernel. Prolamin (protein soluble in 60-80% alcohol) is evenly distributed throughout the kernel and the proportion of Glutelin (protein soluble in dilute acids and alkalis) increases toward the center. The albumins in milled rice have strong amylase activity; the globulins have little. We have analyzed a purified single globulin component, molecular weight 25,500, and found it contained no lysine, histidine, or amylase activity. An analysis of rice bran indicates that the albumins and globulins in the bran differ from those in milled rice.

Infusion with lysine solution raised the lysine level in milled rice to nearly 6%. Addition of soy flour to rice at this lysine level caused color and flavor differences.

Control methods developed at the Western Utilization Research and Development Division are increasing rice drying rates in columnar dryers by 35-40% without additional breakage during subsequent milling.

Contract research has been initiated at the University of California in Berkeley to evaluate the cooking and processing characteristics, utility of new products, and optimum economic balance of products from white rice overmilled to various degrees.

Milk-like products were made with limited success from high protein rice flours using an amylase-pepsin process developed for wheat. Other enzymes tested for their solubilizing effect on the rice proteins were not as effective as pepsin, although three showed promise as acceptable protein-dispersing agents.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Technology -- Process and Product Development

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NEW CROPS UTILIZATION - FEED
Northern Utilization Research and Development Division, ARS

Problem. The research program on new crops is a long-range effort to find new and profitable crops that would have different end-use patterns from those now grown. By providing a wider range of choices, the availability of new crops should enable farmers to achieve more economic use of their land. A more extended discussion of the problems involved in finding and developing a new crop is given under "New Crops Utilization - Industrial Products."

One of the most promising approaches is to search for plants whose seed oils contain potentially useful fatty acids that either are not now available commercially or must be obtained from foreign sources. However, for a new oilseed crop to achieve maximum utility and economic value, it is desirable to obtain, as a byproduct, a palatable and nutritious meal suitable for animal feeds. Thorough investigation is needed, therefore, to determine the probable utility of new oilseed meals as feeds; to discover the presence of possibly undesirable minor constituents; and to evaluate the prospects for successful processing of the oilseed to oil and acceptable meal.

It is possible that a wild plant, although not a potential oilseed crop, might in itself be an advantageous new source of protein or other nutritionally desirable substance. As a part of the broad program on screening and characterization of new plants for potentially valuable components, appropriate effort is required to insure that such a possibility will not be overlooked.

USDA AND COOPERATIVE PROGRAMS

The Department maintains a continuing but limited program involving one professional analytical chemist who devotes a portion of his time to screening uncultivated plants to find possible sources of new amino acids and proteins and to study of amino acids and proteins of meals obtained from new potential oilseed crops.

The Federal program at Peoria, Illinois, totals .4 scientist man-year, all of which is devoted to chemical composition and physical properties.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 6.2 scientist man-years is devoted to research on industrial and feed uses of miscellaneous and new crops.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Components of autolyzed rapeseed meal. Studies have been made involving the structural characterization of the nitrile mixture obtained from a defatted, autolyzed rapeseed meal (Brassica napus). It has been shown that the unsaturated hydroxy nitrile and isomeric episulfides formed were enantiomers of the corresponding compounds derived similarly from crambe meal.

2. Feeding studies on new seed meals. Vernonia meal fed to rats for 90 days at a diet level of 25 percent caused some growth inhibition but no pathological effects. Adding methionine corrected two-thirds of the growth inhibition. Rats fed Euphorbia meal for 4 weeks grew normally, and no harmful effects appeared. These studies were conducted with the cooperation of the Pharmacology Laboratory at the Western Division.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None.

NUTRITION AND CONSUMER USE RESEARCH
Consumer and Food Economics Research Division, ARS
Human Nutrition Research Division, ARS

Problem. The assortment and characteristics of food available to consumers change constantly with the adoption of new practices of production, processing, and marketing. Changing constantly also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help meet the Department's responsibility to advise consumers on the quantity and variety of foods that will assure maximum benefit and satisfaction, research must continue on the nutritional requirements of persons of all age groups, on the nutrient and other values of foods, and on ways to conserve or enhance these values in household and institutional preparation and processing.

The kinds and amounts of foods consumed by different individuals and population groups must be determined periodically so that the nutritional adequacy of diets can be evaluated. Information on food consumption and dietary levels provides the guidelines needed for effective consumer nutrition programs. This information also furnishes the basis for market analyses for different commodities and for development and evaluation of agricultural policies and programs that relate to production, distribution, and consumer use of food.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of improved procedures for household food preparation, care and preservation; (3) nutritional appraisal of food supplies and diets of different population groups; and (4) development of guidance materials for nutrition programs.

The research is carried out by two divisions of the Agricultural Research Service--the Human Nutrition Research Division at Beltsville, Maryland and the Consumer and Food Economics Research Division at Hyattsville and Beltsville, Maryland and Knoxville, Tennessee. Some of the research in both divisions is done under cooperative, contract or grant arrangements with State Experiment Stations, universities, medical schools, hospitals, research institutes, and industry. The total Federal scientific effort devoted to research in these areas is 81.7 man-years. It is estimated that 11.5 scientist man-years is concerned with studies related to cereal products.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and microorganisms concerned with defining human requirements for nutrients and foods are not reported on a commodity basis, though some of the work is applicable to this report. This basic nutrition

research represents a total Federal effort of 19.8 scientist man-years and is described in detail in the report of the Human Nutrition Research Division. Certain aspects of this research related to cereal products are considered briefly in this report.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Nutrient and Other Consumer Qualities of Wheat Products

1. Nutrients in wheat and wheat products. Studies of the nutrient content of wheats and wheat products, collected from 10 cities representative of the continental United States, continue at Beltsville and under research contracts with the American Institute of Baking at Chicago, Illinois, and with the Purdue Research Foundation at Lafayette, Indiana. Analyses for the individual fatty acids and for carbohydrate fractions have been completed. Analyses for riboflavin, thiamine, vitamin B₆, tocopherols, and for at least five mineral elements will soon be completed. Manuscripts reporting the source and preparation of samples and the results of analyses will be prepared and processed during the coming year. Laboratory work on forms of niacin, amino acids, and on trace mineral elements are in progress.

As expected, soft white wheats used for cake and cracker flour were found to be lowest in nitrogen. Hard red winter type wheats used for bread flour were one-fourth higher in nitrogen than the soft white wheats, and durum wheat for macaroni and noodles were one-third more. The starch contents of these wheats were in the reverse order, but not by the same amounts. The riboflavin contents of the wheat grains were very much alike. Durum flour, however, was two to three times higher in riboflavin than other flours. Few differences were observed in fatty acid profiles of the same kind of wheat products from different locations. The kind of shortening used was a large factor influencing these fatty acids in commercial prepared products. Continuous dough bread was higher in linoleic and linolenic acids than conventional dough bread. Some other minor differences in fatty acids were found. The whole wheat products on the retail market were two to eight times greater in copper, manganese, magnesium, and zinc than refined flours or their products. Nickel in hydrogenated shortenings may account for variations in nickel. Nickel was highest in biscuit mix, 0.7 micrograms per gram, and lowest in flours and whole wheat cereals, about 0.2 micrograms. Nickel varied more than other elements in the wheat products analyzed.

The tocopherols are nutritionally important, both because of their vitamin E potencies, and because of their antioxidant activities. Alpha tocopherol has the highest vitamin E potency. The forms and amounts of the tocopherols were similar in all wheat grains, the alpha tocopherol content being about 14 micrograms per gram. Durum wheat was slightly lower in alpha and beta tocopherols, and higher in their unsaturated analogs. More refined flour contained less tocopherol. Cake flour treated with benzoyl peroxide and chlorine contained no alpha tocopherol, and only minor amounts of beta tocopherol and beta tocotrienol. Major differences in kinds and amounts of tocopherols in baked

products were due to the contributions of ingredients other than flour, especially the shortening used. For example, cake was found to contain 30 micrograms of delta tocopherol per gram, 76 of gamma, and 12 of alpha, all from the shortening, plus 2 of beta tocotrienol from the flour. Products made with animal or vegetable shortenings were easily distinguished. Crackers had the greatest variety of forms of tocopherols, containing alpha, beta, gamma, and delta tocopherols, as well as beta tocotrienols. There were wide variations among market areas in the tocopherols in the consumer wheat products, but again these were principally due to the shortening used. For instance, gamma tocopherol in biscuit mix varied, apparently at random, from 0.2 to 66.0 microgram per gram. Wheat has no gamma tocopherol.

In searching for a suitable internal standard to use in tocopherol analyses, a large number of high molecular weight polyesters were prepared and their gas-liquid chromatography retention data determined. This information permits the choice of the best internal standard for a particular sample.

Nuclear magnetic resonance was used to characterize structural details peculiar to the different tocopherols, distinguishing them from one another and from other related compounds. Procedures for the characterization of tocopherols were presented at the 1966 fall national meeting of the American Chemical Society; a manuscript has been published in the Journal of Organic Chemistry.

The vitamin B₆ in whole wheat, whole wheat products, flour, and macaroni occurred mainly as pyridoxine. Baked products contained not only pyridoxine, but equal or greater amounts of pyridoxal and pyridoxamine. Conventional dough bread and continuous dough bread were equal in vitamin B₆ content. Durum wheat was highest in vitamin B₆, containing 3.9 micrograms per gram; hard winter wheats, 3.1, and soft white wheats, 2.8. The vitamin B₆ value in durum flour was twice that of flour from hard red or soft white wheat. Whole wheat is an important source of vitamin B₆ in the diet.

2. Wheat fumigation. No great differences attributable to use of fumigants on stored wheat are apparent in the nutrient content of wheat grain, milling fractions, doughs, or baked products. In a cooperative study, the wheat has been stored in bins in Kansas at atmospheric temperature since the spring of 1965, subject to periodic cleaning and fumigation. Nonfumigated wheat has been stored under the same conditions where it became heavily infested with insects, and also in refrigerated storage (32°) where it remains in good condition. Little accumulation of fumigant residues occurred except for the wheat fumigated with methyl bromide. After 18 months, inorganic bromide has increased ninefold in the whole wheat grains, elevenfold in the patent flour, and tenfold in the baked bread. This indicates that bromide residues are not limited to the surface of the grain. Generally, the tocopherol content of the whole wheat did not change with storage or due to the fumigation treatment. However, some differences in tocopherols and B-vitamins of milling fractions were observed. Further analyses and treatment of the data are needed before final interpretations are made. Storage of the wheat will be terminated in March 1968 after almost 3 years.

Research was continued on the effects of the wheat fumigation on the baking performance of flour for home and institutional use. After 2 years' storage of the wheat, both treated and untreated samples required longer dough fermentation times. Amylograph measurements of flour suspensions showed the phosphine-treated samples to be highest in viscosity and the methyl-bromide fumigated samples lowest of those from wheats stored at ambient temperatures. Changes in gelatinization temperatures of the starch, measurements of enzyme activity in the grain, and analyses of phosphates will be made on selected samples to explain some of the differences due to fumigation. Amino acid analyses of wheat and flour samples are being made to determine if any amino acids have been methylated by methyl bromide. This research is still underway.

3. Lysine fortified wheat flour. Studies were made to determine whether free lysine added to wheat flour would be lost during baking. Flours with no added lysine (as control) and flours to which lysine hydrochloride had been added at 0.1 to 0.6 percent levels were used in making doughs, chapatis, and breads. Only 3.8 percent of the added lysine was lost on cooking chapatis, while in bread the loss was 25 percent. The larger loss upon baking bread may be due to the much greater cooking time.

To determine the palatability of wheat fortified with lysine and destined for shipment to India, granular whole-wheat (attas) containing 0.1 to 0.6 percent L-lysine monohydrochloride were prepared at the Western Utilization Research and Development Division. Attas of a higher extraction (93 percent) were made into chapatis and attas of a lower extraction (85 percent) were made into yeast bread. Sensory quality evaluations of both types of bread were conducted to determine effects of lysine fortification on color texture, and flavor of chapatis and on flavor of yeast bread. The panel members, in those instances where they thought they detected a difference in flavor between untreated and treated samples, preferred the flavor of the lysine chapatis from 63 to 79 percent of the time. A manuscript describing this work is in preparation.

4. Home and commercial bread formulas compared. During the first 12 months' storage of the wheat fumigation study (see above), flours milled from the non-fumigated wheats were used to make both home-type and commercial-type breads. Breads made from home-type formulas using ingredients available to homes and institutions had better grain texture and were more tender than breads made with commercial-type formulas and with commercial-type ingredients. Commercial-type breads, however, were higher in loaf volume. This was the first known study in which the same flour was evaluated in both home and commercial use situations. The results indicated that either method may be used to evaluate the quality of wheat flour. A paper "Assessing Wheat Quality with Home- and Commercial-Type Breads" was presented at the Amer. Assoc. of Cereal Chemists meeting in Los Angeles, California, April 1967. A manuscript has been prepared for publication.

B. Evaluation of Cereal-based Products

Research was initiated on quality evaluations of a variety of cereal-based foods intended for purchase in the Food for Peace Program. These foods were combinations of two or more of the following: Wheat, wheat blends, oats, corn,

soy, and millet. Some blends were for use as beverages and porridges while others were intended for making batter-type rolls and Asiatic-type breads such as chapatis, arabis, and shamsi. Physical measurements of the product quality included gel strength, viscosity of hot and cold pastes, gelatinization temperature, dough strength, density, settling of the dry mixture, and stability of the cooked suspensions. A taste panel of five staff members evaluated quality characteristics such as appearance, aroma, texture, and flavor of each experimental sample compared with a reference sample. Results of these evaluations are considered in the Department in making recommendations for the purchase of foods for the Food for Peace Program.

C. Nutritional Evaluation of Grain Products

1. Evaluation of wheat. Contract research on the nutritional value of wheat protein has been completed and manuscripts giving the results are being prepared for publication. At Michigan State University, 12 young men achieved nitrogen balance on diets supplying approximately 66 grams protein per day, all from plant sources and 90-95 percent of which was provided by wheat. During the 50-day study, protein components in the blood were not changed significantly. However, the blood urea level was reduced by approximately 50 percent on the wheat diet, with a gradual reduction in urinary urea excretion. Urinary excretion of essential amino acids was related to dietary intake. Fasting plasma free amino acids were within normal limits throughout the study. The plasma levels of lysine and valine were reduced during the first 25 days on the wheat diet and remained constant thereafter. The reduction in plasma lysine may be attributable to a reduction in dietary lysine. The reduction in valine took place despite the constancy of its intake with both the prestudy mixed protein diet and the controlled wheat diet. The reduction, therefore, may be reflecting lower availability of valine in the wheat diet. There was no significant change in serum levels of total lipids, cholesterol, or phospholipids.

Vitamin and mineral analyses were completed at the Agricultural and Technical College of North Carolina, Greensboro, where 12 young men were maintained in positive nitrogen balance during four 15-day test periods on diets containing 47 grams plant protein per day, of which 35 grams (75 percent) were supplied by wheat or wheat supplemented with pinto beans, rice, or peanuts. The analyzed dietary intake of niacin as determined microbiologically was approximately half of the calculated content. The analyzed daily dietary intakes of vitamins B₆ and B₁₂ were both much lower than the calculated values and as a result, the intakes were lower than suggested by the National Research Council as minimal. During the short duration of the study, these low intakes appeared inconsequential. These differences in analyzed and calculated values reflect the variation in vitamin content within food groups and illustrate how nutrient content may vary from the weighted average values given in tables of food composition. No information on the significance of dietary changes on vitamin and mineral metabolism will be available until the contractor has analyzed the data statistically. During the year, portions of this research were presented at the International Congress of Nutrition, Hamburg, Germany, August 1966, and at the Federation of American Societies for Experimental Biology in Chicago, Illinois, April 1967. A manuscript giving the results is being prepared for publication.

2. Nutritional value of carbohydrates. A dietary study with 10 young men (19-23 years old) was conducted to compare the nutritional value of wheat starch with sucrose. In this study, the young men ate diets identical in composition to those in an earlier study of young women and reported in the 1966 Report (D-2; p. 333). In these diets, 85 percent of the carbohydrate was provided by wheat starch or sucrose during 30-day dietary periods. To meet the greater nutrient needs of the young men, the quantity of all foods in the diets was increased by approximately 50 percent over the quantity eaten by the women. The men's serum levels of lactate dehydrogenase, alkaline phosphatase, aldolase, and the two transaminases were significantly higher with the sugar diet than with the starch diet. Most of the levels observed were within the normal range for the enzyme under study. The levels of aldolase were in the borderline area (slightly above normal) in three subjects initially, in two subjects after eating the starch diet, and in seven subjects after eating the sugar diet. The significance of these observations is not clear at present, but it seems likely that starch and sugar were metabolized by different pathways or at different metabolic rates or both. A portion of this research was reported at the Federation of American Societies for Experimental Biology in Chicago, April 1967. A manuscript is being prepared.

To help explain some of these observations, research on the early metabolic effects of different kinds of carbohydrates upon various components of blood and urine of men and women has been initiated under a grant at the University of Alabama at University. The carbohydrates proposed for study include glucose, fructose, sucrose, wheat starch, and cornstarch. Blood will be analyzed for changes in enzymes such as lactate dehydrogenase and its isozymes and for carbohydrate metabolites such as glucose and pyruvic acid for several hours following the test meal. Urine will be analyzed for various nitrogenous components and mineral elements.

3. Heredity and carbohydrate utilization. Research at Beltsville is providing evidence that protein and mineral metabolism as well as lipid metabolism may differ with the kind of carbohydrate in the diet and with the inherited characteristics of the animals under investigation.

During this year, four papers have been completed reporting the results of the long-term feeding of cholesterol-containing diets with the carbohydrate supplied as sucrose, glucose, and cornstarch. The findings dealing with the liver and serum lipids and the histology were described in last year's report (see 1966 report, D-3, p. 333). The paper dealing with the influence of type of dietary carbohydrate on the histological findings has been accepted for publication in the Archives of Pathology. A paper dealing with the effect of dietary carbohydrate on serum protein components has been accepted for publication in the Journal of Nutrition. A manuscript on the effect of type of dietary carbohydrate and age on magnesium, calcium, and phosphorus metabolism has been prepared. A fifth paper is in preparation and will include the results of food intake, weight gain, and body composition as influenced by the kind of dietary carbohydrate.

The influence of the kind of carbohydrate on the protein components in the blood depended on age, state of fast, and strain of rat investigated. The greatest differences were observed in a protein component (PA) moving more rapidly than albumin in an electric field. The incidence, that is the relative number of rats containing this component in their blood, as well as the level of PA in the blood varied with the experimental conditions.

Differences due to dietary carbohydrate were seen more frequently in the blood obtained from rats after an overnight fast than from nonfasted animals. In one strain (BHE), level and incidence of PA increased with age in the blood of fasted animals that had received the diets containing sucrose or starch. Extremely high levels were observed with sucrose. With glucose, the incidence was high at both 150 and 350 days of age, but the level was consistently low. In a second strain of rats (Wistar) fed sucrose, the level and incidence of PA were both high at 150 days, but low at 350 days; by 350 days no significant differences due to carbohydrate were apparent. The level of PA in the blood correlated directly with the level of fat in the blood, suggesting that this component, previously shown to be associated with fat, may play a role in fat transport.

The kind of carbohydrate also was found to influence significantly the calcium and magnesium content of the kidneys of the BHE rats. Here, too, heredity was apparently a factor in determining the extent to which levels of kidney calcium differed with dietary carbohydrate. Calcium levels were higher in the kidneys of BHE rats when the diet contained sucrose than when the diet contained starch. When sucrose was fed, the level of calcium was much lower in the kidneys of the Wistar rat than in the kidneys of the BHE rat, a strain generally susceptible to kidney damage and dying at an early age on this diet. The magnesium levels in the kidneys of both strains were higher in the animals fed sucrose than in those fed starch but no differences due to heredity were observed.

A project initiated last year under contract with the Hazleton Laboratories at Falls Church, Virginia, is progressing rapidly and close contact with the developments from this research has been possible because of the computer facilities available at the Hazleton Laboratories. This investigation is providing more information on heredity as a factor in response to diet as well as further evidence of differences in fat metabolism with the kind of dietary carbohydrate. The use of cooked cornstarch in place of the raw cornstarch that was used in our previous studies has resulted in some unexpected differences in food consumption and weight gain. The contract has been amended to include measurements of digestibility of the diets and the fecal excretion of bile acids and sterols.

4. Protein-carbohydrate interrelationships. Research using a protozoan, Tetrahymena pyriformis, with nutritional requirements and metabolic responses similar to those of higher animals, is providing further evidence concerning carbohydrate and nitrogen relationships. The marked inhibition of this

organism by the amino acid serine has been found (1) to be related to type of carbohydrate, (2) to be affected by past dietary history, and (3) to be overcome as the length of the incubation period is prolonged. When the medium contains glucose, inhibition is slight; the presence or absence of glucose in previous culture media has little effect on growth response. In contrast, when the carbohydrate is dextrin, inhibition by serine is pronounced, and was greater with cultures which had previously been maintained on media containing glucose or dextrin. The inhibition is largely reversed by intermediates of the citric acid cycle, by amino acids that enter readily into this cycle, by pyruvic acid, and by glucose.

D. Tables of Food Composition

1. B-vitamins in foods. Summarization of data and derivation of representative values for a publication on the content of pantothenic acid, vitamin B₆ and vitamin B₁₂ are now complete for some 700 items of food. The values will provide the basis for evaluating food supplies and diets with respect to these vitamins.
2. Nutritive value of retail and household units of food. The development for publication of a table showing nutritive values of foods in terms of common retail and household units is continuing. Values will be given for proximate composition, calcium, phosphorus, iron, sodium, potassium, vitamin A, thiamine, riboflavin, niacin, ascorbic acid, and selected fatty acids. Final values are now ready for more than 500 items of food and are nearing completion for many others.
3. Revision of Handbook No. 8. Work to obtain data for the next revision of Agriculture Handbook No. 8, Composition of Foods, is proceeding along several lines.
4. Amino acid content of foods. An extensive search for published and unpublished data on the amino acid content of foods is underway.

E. Food Consumption and Diet Appraisal

1. 1965 nationwide survey. Analysis of the household data showed that families surveyed in the spring of 1965 spent 36 cents of their food dollar for meat, poultry, fish and eggs; 19 cents for vegetables and fruits, including juices; 13 cents for milk and milk products; 12 cents for flour, cereals, and bakery products; 10 cents for beverages other than milk and juice; and 10 cents for fats, sweets and all other foods. This division of the food dollar varied little among groups of families whether classified by region, urbanization or income. Choices within these broad groups did vary. For example, farm families used more flour, fat, sugar, and eggs per person and less bakery products than city families. Southern families used the most pork, poultry, and fish and the least beef; western families used the most beef.

Families surveyed in the spring of 1965 used more beef and poultry and less pork, fish and eggs than families surveyed in the spring of 1955. The families

surveyed in 1965 also used more frozen milk desserts, cheese, dry and fresh skim milk and less fresh whole milk, cream, and evaporated milk; more canned and frozen vegetables and fruits and less fresh vegetables and fruits; more breakfast cereals and bakery products other than bread and less flour, bread and cereals other than breakfast cereals; more margarine and oils and less butter and shortening. Many of the changes reflected the trend to increased use of commercially-prepared foods. There was also greater use in 1965 of foods associated with snacking--ades and punches, soft drinks, potato chips, luncheon meat, peanut butter, crackers, cookies, doughnuts and candy.

Papers reporting findings on the food consumption of households in spring 1965 were presented at three National meetings. One preliminary report was published and a second was prepared for publication. Final reports are in preparation--one for the U.S. as a whole and one for each of the four census regions. These reports will provide information on the percentage of families using major groups, subgroups, and selected items of foods as well as the quantities and money value of the foods consumed. This information will be given separately for urban, rural nonfarm, and rural farm families and for all urbanizations combined. Another classification will be by income of family.

2. 1967 survey in Mississippi. In May 1967, a survey was made to evaluate two types of food distribution programs in two counties in the Mississippi Delta. The survey was made by the Consumer and Food Economics Research Division, ARS, in cooperation with the Economic Research Service. In Washington County, a Food Stamp Program had replaced a Food Donation Program in March 1967. In Sunflower County, a Food Donation Program of long standing was in operation. The families surveyed included participants and eligible nonparticipants in both the Food Stamp Program and the Food Donation Program.

Preliminary evaluation of the data indicated that the average diet was poor. Foods most needed to improve the diets of these families are milk products, vegetables and fruits. Diets of families who participated in the food program were similar in many respects to those who were eligible but did not participate.

Money value of the food used averaged about \$4.00 a person a week (including value of free food stamps and donated commodities). This is about 25 percent less than the cost of the USDA Low-cost Food Plan for the South. On the average the families included in the survey spend about one-half of their incomes on food.

Data on height and weight were obtained as an indication of the growth and nutritional status of children 2 to 12 years old in the families surveyed and are being evaluated by the Human Nutrition Research Division.

3. Preschool children in Hawaii. Data needed to assess the nutritional situation of children 2 to 3 years of age in low-income families and middle-income families in Honolulu have been collected. Included are a 3-day record of the child's food intake, a physical examination record, and information on the child's early diet, on the mother's food practices and attitudes, and on

the family's socioeconomic situation. Data collected in biochemical, clinical, and psychomotor tests are being evaluated. The research is being carried out by the University of Hawaii under cooperative agreement with the Consumer and Food Economics and the Human Nutrition Research Divisions.

4. Nutritive value of the national food supply. Food energy (calories) and selected nutrients provided by the per capita food supply are estimated each year by the Consumer and Food Economics Research Division from data on apparent civilian consumption, retail basis, developed by the Economic Research Service. The estimates show that shifts in food consumption over the years have resulted in changes in the sources of fat, carbohydrate and protein. Vegetable fat now accounts for a higher percentage of total fat because of the shift from butter to margarine and from lard to shortening and the sharp increase in use of salad and cooking oils. The share of calories derived from total nutrient fat which increased from 1909 to the early 50's has changed little since. Saturated fatty acids account for a smaller share of the total fat today than they did 55 years ago--37 percent compared with 40 percent--even though the American diet now contains more fat. Oleic acid continues to account for about 41 percent of the total fat. The share attributed to linoleic acid has been increasing and is now roughly 13 percent. Starch and sugars now contribute about equally to total carbohydrates; in 1909-13, two-thirds was provided by starch and one-third by sugars. Animal products contribute two-thirds of the protein today compared to one-half 55 years ago.

5. Nutrient content of Type A school lunch. A nationwide study of the nutrient content of Type A lunches served to 6th graders is being carried out by the Consumer and Food Economics Research Division in cooperation with the School Lunch Division, Consumer and Marketing Service. The study was undertaken to obtain data needed for evaluating the Type A pattern. Twenty lunch composites from each of 300 schools in 19 states in 5 geographic regions have been analyzed by a contractor, the Wisconsin Research Alumni Foundation, for proximate composition, fatty acids, and 12 minerals. Analyses are in progress for seven vitamins, iron and residues of chlorinated hydrocarbon insecticides.

In general, the lunches met the nutritional goal of one-third of the 1963 NRC Recommended Daily Dietary Allowance for 9 to 12 year olds for energy, calcium and protein. The average energy level of the lunches from the 300 schools was 735 Calories--the goal for girls and a little under the goal of 800 Calories for boys. On the average, 39 percent of the calories were provided by fat in the lunches. The average calcium content was 400 milligrams per lunch--a little more than the goal of 367 milligrams. For protein, all lunches met the goal of one-third of the Recommended Daily Allowance for 9 to 12 year olds--18.3 grams for girls and 20 grams for boys.

6. Acceptance of Type A lunches. A study of factors affecting acceptance of the lunch program by 10th grade students in Louisiana is being carried out under cooperative agreement with Louisiana State University. Thirty students

from each of 17 schools, their parents and the officials of the schools provided information for the study. Included were urban and rural schools, large and small schools, and schools with low, medium and high levels of participation in the lunch program.

F. Support for Food and Nutrition Programs

1. The fifth national Nutrition Education Conference was held in Washington, D.C., February 20-22, 1967, with about 275 persons representing a wide variety of agencies and disciplines from most of the states. The theme was "effective communication" and coordination of nutrition programs as a means of facilitating behavioral changes in eating habits. The Conference was cosponsored by the Consumer and Food Economics Research Division and the Interagency Committee on Nutrition Education.

2. Bimonthly publication of Nutrition Program News, which reaches some 7,000 workers in nutrition and related fields was continued.

3. Technical assistance to programs. Nutrition research findings continue to be studied and interpreted for application to problems in food selection and food use. Technical assistance was given by nutritionists to programs of other government agencies such as the food and nutrition programs of Project Head Start, Office of Economic Opportunity. Talks to groups involved in community nutrition programs, radio and TV tapes on nutrition, and consultant help and participation in conferences contributed to coordination and strengthening of nutrition programs.

4. Food for low-income families. Recipes developed for rolled oats, peanut butter, and raisins were prepared by the Human Nutrition Research Division for distribution to low-income families participating in the USDA food distribution program or the Food Stamp Program. These supplement the series of 17 leaflets on a variety of commodities prepared earlier and now available for national distribution as part of the Department's participation in the Federal program to combat poverty. This work, in cooperation with the Consumer and Marketing Service, will be continued. Negotiations were completed with the University of Maryland to have USDA recipes tried and evaluated by low-income families living in housing developments in Washington, D.C.

5. National school lunch program. Research on large quantity food preparation and food quality in the Human Nutrition Research Division has provided help to school lunch managers across the nation to make the best use of donated food commodities available to them and other foods obtained on the local market. "Favorite" recipes from schools were standardized and published for other schools to try. A survey of pupil acceptance of these recipes in about 100 schools in five areas of the United States is in progress. Food uses for peanut butter and raisins were developed to help schools use the large quantities distributed to them.

6. Project Head Start--food buying guide and recipes. A 130-page manual prepared by the Human Nutrition Research Division for the Head Start Program of the Office of Economic Opportunity gives quantity recipes and food buying guides needed to prepare nutritionally adequate meals for groups of 25, 50, or more preschool children from low-income families. Food served in Head Start Centers must be inexpensive to buy, easy to prepare with limited kitchen equipment, and attractive and appealing to small children.

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III. MARKETING AND ECONOMIC RESEARCH

GRAIN - MARKET QUALITY

Market Quality Research Division, ARS

Problem. Grain and cereal products are subject to damage, contamination, or deterioration in quality while in the marketing channels. These adverse effects may result from normal metabolic changes, the action of microorganisms, the attack of one or more of some 50 different kinds of common stored-product insects, or pesticide residues left by control measures applied against the insect pests. The damage may be conspicuously evident or insidiously hidden; may result in destruction of nutrient values or the presence of undesirable substances in food and feed; or insects may render products aesthetically unacceptable. Such deterioration affects the grade and price received, and end use, the wholesomeness of the product, and the competitive position of U. S. commodities in the world market. Research is needed to protect this multibillion dollar crop from outright destruction, evident deterioration, and hidden damage, especially as the need for food and animal feed becomes more critical throughout the world. The standard procedures that were formerly acceptable are becoming obsolete as a critical market demands higher quality, as international pesticide residue tolerances are in the process of being adopted, and as supply lines lengthen through overseas shipment in a worldwide distribution pattern. New methods of protection against insects and disease, of identifying and measuring quality changes, and means of maintaining quality over longer periods of time and under adverse conditions are some of the problems requiring attention.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving chemists, engineers, and plant pathologists in basic and applied research on the quality evaluation, quality maintenance and development of objective methods for quality evaluation of cereal grains. The research is conducted at Beltsville, Maryland and also by contract with the University of Arkansas, Fayetteville, Arkansas and by cooperative agreement with Purdue University, Lafayette, Indiana and the University of Missouri, Columbia, Missouri and a grant with the University of Minnesota.

The Field Crops & Animal Products Research Branch Federal scientific effort in this area totals 18.7 scientist man years: quality evaluation 16.7, and quality maintenance 2.0.

PL 480 projects include a grant to the Institute for Cereals, Flour and Bread, TNO, Wageningen, Holland, providing for the development of simple, reliable and accurate tests to determine relative hardness of wheat for the

purpose of devising a system of classifying wheat for use in official grading and inspection. Its duration is for 4 years (1965-69) and involves \$70,670 equivalent in Dutch guilders.

A grant to the Instituto Nacional de Investigaciones Agronomicas, Madrid, Spain, provides for a study to develop and evaluate equipment and methods for determining the proportions of durum (semolina) and common wheat (farina) in macaroni and spaghetti products. Its duration is for 5 years (1964-69) and involves \$43,563 equivalent in Spanish pesetas.

There is also a continuing Department program involving entomologists and chemists engaged in basic and applied research on problems of insect infestation, damage, and contamination of grains and cereal products in the marketing channels. The research is conducted at Manhattan, Kansas and at Tifton and Savannah, Georgia, in cooperation with the respective State Agricultural Experiment Stations, the Transportation & Facilities Research Division, the Agricultural Stabilization & Conservation Service, farmers' cooperatives, the Association of Operative Millers, the American Corn Millers Federation and other industry groups. The Commodity Credit Corporation makes available various commodities and storage facilities for experimental use, thus greatly facilitating the program. There is also overall cooperation with several State Agricultural Experiment Stations through participation in Regional Project WM-52 "Maintaining marketability of stored grain and cereal products through insect control by methods leaving no, or a minimum of, pesticide residues."

There are four cooperative agreements with the Kansas State University as follows: (1) a 3-year study for research on the biology and behavior of the Angoumois grain moth, through December 1968, (2) a 2-year study of insect infestation in bulgur and methods for prevention, to April 1969, (3) a 3-year study of the physiology of water balance in the yellow meal worm, to June 1970, and (4) a 2-year study of the fate of malathion residues on grain sorghum, to June 1969.

A 2-year cooperative agreement with the University of Wisconsin continues until April 1969 for a study of the bacteria occurring in the alimentary canals of the gramary weevil and the lesser meal worm.

A 2-year grant to the California State College of Los Angeles continues until June 1969 for research on the effects of grain sorghum varieties on the development of two species of rice weevils.

A 1-year cooperative agreement developed jointly by the Market Quality and Entomology Research Divisions with the University of Maryland continues until June 1968 for research on the biology and ecology of the lesser meal worm in relation to transmission of leukosis to chickens.

A grant to the Indian Agricultural Research Institute, New Delhi, India, for a 3-year study of varietal resistance of wheat kernels to damage by the rice weevil and lesser grain borer continues until February 1968 and involves PL 480 funds with a \$15,146 equivalent in Indian rupees.

A grant to the Tokyo University of Agriculture, Tokyo, Japan, for a 3-year study, part of which is on the constituents of wheat that attract insects, continues until August 1968 and involves PL 480 funds with a \$38,622 equivalent in Japanese yen.

A grant to the Maharaja Sayajirao University of Baroda in India for a 5-year basic research study on the physiology of fat metabolism in relation to diapause in the khapra beetle continues until January 1970 and involves PL 480 funds with a \$33,907 equivalent in Indian rupees.

A grant to the University of Helsinki in Finland for a 5-year study on the effects of pesticides on plant commodities, part of which deals with malathion on wheat, continues until December 1969 and involves PL 480 funds with a \$96,441 equivalent in new Finnish finnmaks.

A grant to the National Botanic Gardens, Lucknow, India, for a 5-year study on plant extracts and isolates having pesticidal properties continues until December 1971 and involves PL 480 funds with a \$63,506 equivalent in Indian rupees.

A grant to the Hebrew University, Jerusalem, Israel, for a 3-year study on pheromones produced by the khapra beetle continues until March 1970 and involves PL 480 funds with a \$96,258 equivalent in Israeli pounds.

A grant to the University of Zagreb in Yugoslavia for a 5-year study of non-pesticidal control measures for stored-product insects continues until April 1972 and involves PL 480 funds with an \$84,154 equivalent in new Yugoslav dinars.

The Federal Stored-Product Insects Research Branch effort on the prevention of insect infestation was 7.8 scientist man-years, of which 0.2 was under a cooperative agreement. Much of the cross-commodity research reported in Area 13 "Insect Control in Marketing Channels," is also applicable to the problems in grain.

PL 480 project S9-AMS-6(a), a study in Uruguay on hermetic storage of corn, was terminated at the end of the 5-year grant period.

PL 480 project A10-AMS-4(a), a study in Israel on the effect of ethylene dibromide fumigant on farm animals, was terminated at the end of the 5-year grant period.

PL 480 project A10-AMS-11(k), a study in Israel on the biology of the khapra beetle, was terminated at the end of the 5-year grant period.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 20.4 scientist man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective Measurement and Evaluation of Quality

1. Flour-Yielding Capacity of Wheat. The relation of hardness measurements to the milling quality of wheat is being investigated, but no conclusions can be drawn at this time.

The curves from the Hardness Tester denote the soft or hard characteristics of the wheat. The hard red winter wheats produce higher peak values than do the soft red winter wheats. Peak values within the wheat class indicate the degree of hardness or softness. Hard red winter wheats ranged from 425 to 610 Brabender units. Soft red winter wheats ranged from 335 to 535 Brabender units. Increased moisture content was found to decrease the peak value and increase the curve length. If the samples are tested between 8 and 11% moisture, the effect of moisture content is minimized and the curves can be compared.

The effect of kernel size on the hardness measurement was also studied. Samples of each class of wheat were separated into three kernel sizes by sieving. The small kernels produced lower peak values and slightly longer curves.

2. The Effect of Stinkbug Damage on Soybean Quality. Oil content of heavily damaged soybeans averaged a fraction of a percent lower than that of slightly damaged soybeans but protein content in the more heavily damaged beans was a little higher. After storage for 6½ months, soybeans ranging in moisture content from 10 to 14% averaged 0.42% lower in oil content and 22.84% higher in fat acidity. Protein content decreased by 0.42%. Damaged soybeans stored for long periods undergo greater increases in fat acidity than undamaged beans.

3. Identification of Storage Fungi. The Biospect recording spectrophotometer was adapted to record reflectance measurements (at 350 to 850 mμ) of spores deposited on filter paper by using glass fiber optics and a special sample holder. By this means, 12 species of the fungus, Aspergillus, were identified according to reflectance characteristics of their spores.

4. Detection of Mixed Corn. A method has been developed for detecting lots of corn in which high-moisture corn has been mixed with low-moisture corn (usually artificially dried and often heat damaged). The method involves determining the moisture content of individual kernels in a sample. There is a greater range of moisture content of kernels in a mixture.

5. Quality Evaluation of All-Purpose Flour. This study covered 26 samples of all-purpose flours delivered east of the Mississippi River. Comparisons of the following analyses were made: Amylograph versus falling number values; falling number versus diastatic activity (maltose); falling number versus loaf volume; loaf volume versus diastatic activity (maltose); falling number versus cookie factor.

The highest degree of correlation was found between (1) amylograph values and falling numbers (0.921), and (2) the falling number and diastatic activity (maltose) (0.893). None of the other relationships were significant. Both of these tests are measures of alpha amylase activity but by somewhat different techniques.

The all-purpose flours were studied also for their gravymaking properties. The MacMichael Viscosimeter ranked the flour for gravymaking in the same order as the falling number test and amylograph with few exceptions.

6. Sampling Research. Three diverter-type mechanical samplers were installed and tested under conditions simulating country elevator operations. Two grain flow rates, two spout slopes, three sampler locations and four levels of homogeneity were studied. Performance of the three mechanical devices and the pelican were compared using wheat containing known percentages of corn and screenings. Component levels exceeding normal levels found in market channels were used to provide a challenge for the sampling devices.

In overall performance, the three mechanical samplers did not differ significantly. They were not biased by flow rate, spout angle, or position along the spout within the conditions of the tests. The pelican performed as well as the mechanical devices except it was slightly more variable.

Handling during the testing procedure caused a rapid increase in the homogeneity of layered grain but did not result in a mixture approaching complete homogeneity.

Sampling research was performed at Minneapolis, Denver and Omaha on hopper car quantities of corn, wheat and soybeans handled at flow rates normally used when loading hopper cars. The grain was also sampled while at rest in covered hopper cars, using three types of probes.

When sampling the same grain more accurate and less variable samples were obtained with the mechanical sampler than with probes. This was true for all three kinds of grain and for diverter slot widths of 0.75 inch and 100 feet per minute velocity across the grain stream. Diverter velocities were increased up to 200 feet per minute without significant loss in performance; however, a decrease in slot width from 0.75 to 0.50 inch showed a significant decrease in performance when sampling soybeans containing 5% of weed seeds as the additive.

Research on grain velocity effects at the diverter of mechanical samplers was conducted in a commercial elevator at Minneapolis. Lots of both fragile corn and tough wheat were sampled after vertical free falls of 1 foot, 50 feet and 90 feet. There was no measurable increase in broken corn in the sample after 1 foot of free fall but at 50 and 90 feet the increases were highly significant. Wheat samples were not significantly different at the three sampling locations.

7. Automatic Moisture Meter. A 2-year contract was let to develop an automatic moisture instrument which will give the average moisture content as well as the moisture range in the grain sample.

8. Optical Characteristics of Grains. Investigations designed to establish the feasibility of using optical characteristics for identifying specific grains, weeds and foreign materials in a grain sample have been started under a 2-year contract.

9. Automatic Test Weight Device. An automatic test weight device is being developed under a 1-year contract.

10. Isolating Germ of Grains. Research to develop a method and to design equipment for isolating and concentrating the germ of grains was initiated under research contract.

11. Sound Grain Determination. Under contract, work has been started in an attempt to develop procedures and methods for objectively determining the percentage sound grain in a sample.

12. Kernel Hardness of Wheat. The ability to differentiate between soft and hard wheats (in hardness) seemed to be greatest when a particle size sieving test was used and least when a Smetar penetrometer was used. Since moisture content and kernel size are important factors in degree of hardness, samples of wheats, of different kernel size and varying moisture contents, are being studied to determine how the various test methods respond to these variations.

13. Macaroni and Spaghetti Products. The presence of sitosteryl palmitate, determined by a modification of the Matweef method, has not shown very promising results for measuring the different proportions of common (Triticum aestivum) wheat and durum (Triticum durum) wheat flours in macaroni products. Studies on the lipids, proteins and lipoproteins have been undertaken to obtain a better differentiation between the two types of wheat.

B. Quality Maintenance in Storage

1. Changes in Wheat Due to Insecticides. Wheats treated with Cab-o-sil, Silica Aerogel 68, Perma Guard and Kenite showed no further decreases in test weight per bushel and no change in the yield of flour as compared with the untreated wheat when storage period was extended another year. Malathion-

treated wheat did not change in test weight or yield of flour. The different dusts or liquid insecticide materials appear to have no effect on the fat content of the treated samples. In the third year of storage, fat acidity increased in both control and insecticide-treated wheats, with changes averaging higher than in any one year's tests. Diastatic activity (maltose) increased in all the wheats except the Kenite-treated sample which remained relatively constant. The mixing peak by the farinograph in the physical dough tests remained relatively unchanged along with the absorption for the control and insecticide-treated samples. The hot breads from both the control and treated wheats had a stale odor.

2. Quality Changes Due to Fumigation. A cooperative study with the Human Nutrition Research Division on the quality changes in wheat due to fumigation and storage is in progress. Two controls (outside, held at ambient temperatures, and cold, held at 32°F.) and three fumigated wheat samples treated with (1) phosphine, (2) methyl bromide, and (3) three parts of ethylene dichloride plus one part carbon tetrachloride comprise the samples being studied.

The results of chemical and milling tests indicate that the three fumigated wheats were not materially different in any one of the quality factors from those of the outside control or the cold control samples. There were some minor decreases in sedimentation values for each of the lots of the controls and treated wheats. It is known, however, that sedimentation values generally decrease during storage of normal wheat.

There were no important changes in the physical dough tests for the samples.

Averages of the quality characteristics of triplicate bakings for the various testing periods show no important changes between the controls and the fumigated wheats. Sensory examinations were made of the bread baked from the controls and fumigated wheats at the time the loaves were taken from the oven. The hot breads baked from the fumigated samples were found to be normal in odor and similar to the bread baked from the control samples.

3. Quality Changes Due to Insect-Resistant Cotton Bags. Chemical and baking tests were carried out on samples of regular cornmeal (with germ), degermed cornmeal and all-purpose flour in cotton and other various types of bags treated with different dosages of an insect-resistant material, pyrethrum-piperonyl butoxide and stored in an insect exposure area. Untreated samples, not stored in insect exposure area, were included as controls.

Chemical analyses of two samples of all-purpose flour both stored in the same type of cotton bags without liners indicate that the lot with the high insecticide treatment had about three times more residue left in the commodity than the other lot.

The only difference in the analysis between the samples was in the bread crumb grain which was materially better for the high residue sample. Significantly higher fat acidity values, loaf volumes and bread crumb grain were found in the high residue sample as compared with the control sample. Flour in the other three bag types (two cotton bags with waxed Kraft paper liners, one low in commodity residue and the other residue free, and paper bag with no residue in commodity) increased significantly in fat acidity during storage compared with the control sample. Other important differences were increases in loaf volume for the cotton bags with waxed paper liners (low residue in commodity) and changes in loaf volume, bread color and grain for the untreated cotton bags residue free with waxed paper liners.

Cotton bags without liners, in which two types of cornmeals were stored, received high and low dosages of insecticide material resulting in high and low residue content in the meal. The samples of low residue content developed much higher fat acidities than samples of higher residue content similarly stored.

There were progressive increases in fat acidity values for the degermed cornmeal stored in the other bag types, i. e., treated cotton bags with waxed paper liners, paper, and untreated cotton bags with waxed paper liners. The first two bag types were treated with medium and low dosages of insecticide material, respectively, while the third bag type had none. No differences were found in fat acidity values for regular cornmeal in these same three bag types. The degermed cornmeal produced higher fat acidities than the regular cornmeal even though it was lower in fat content. The finer granulation of the degermed meal may be responsible.

C. Prevention of Insect Infestation

1. Biological and Physical Control. After 36 months of a long-term storage test with shelled corn in 500-bushel bins in Georgia none of two diatomaceous earths, two silica aerogels, or a malathion treatment was any longer effective. There was a high level of insect infestation in probe samples from all five bins of each treatment. When the bins were unloaded after 42 months of storage representative samples of corn were taken from the grain stream for insect counts, which were lower than those from the probe samples at 36 months. The malathion treatment averaged 24.4 live insects per 1,000 grams. The lowest inert dust was a silica aerogel with 49.6 and the highest was a diatomaceous earth with 83.9. The predominant insects in decreasing order of abundance were the lesser grain borer, long-headed flour beetle, flat grain beetle, and red flour beetle. Weight records were kept on each bin so loss by insect attack and other factors could be determined. At load-out after 42 months, corn with the malathion treatment had lost 6.5% in weight, with the inert dusts 8.1 to 15.0%, and the untreated check 17.8%. No determination was made of the amount of extraneous material such as insect frass remaining in the grain but it was considerable where there was heavy infestation. The inert-dust treatments affected flow rate

and speed of grain movement less at load-out than at load-in. Rate of flow was only 19% less than the malathion treatment at load-out but the reduction was 43% at load-in.

Malathion and one of two diatomaceous earths tested were effective in preventing insect infestation for 3 years in dry wheat ranging 10 to 12% moisture and stored in 3,250-bu. circular metal bins in Kansas. Another diatomaceous earth and two silica aerogels were not effective. All check bins of untreated wheat became heavily infested.

Two diatomaceous earths and one silica aerogel kept shelled corn in the 12 to 13% moisture range insect-free for 3 years, stored in 3,250-bu. circular metal bins in Illinois. A second silica aerogel was only slightly less effective. Malathion kept the corn insect-free the first year, three bins of five were lightly infested after 2 years with an average of 0.24 insect per 1,000 grams, and all five bins were infested after 3 years with an average of 3.5 insects per 1,000 grams. (Unclassified)

In replicated 4-bu. bin tests, a silica aerogel at 60 pounds per 1,000 bu. of hard red winter wheat gave almost complete protection against the lesser grain borer for 12 months. A diatomaceous earth and the standard malathion treatment were slightly less effective.

Concentrations of more than 35% of carbon dioxide and less than 14% of oxygen were maintained for 4 days in the interstitial atmosphere of wheat in 500-bu. metal bins when purged with carbon dioxide. This combination was shown in laboratory tests to be effective in controlling many stored-grain insects. An inexpensive recirculation system was designed for the 500-bu. bins, along with a set of control devices for the automatic application of the carbon dioxide to maintain the desired concentrations of atmospheric gases. The control system uses a solenoid, a timer, and a flometer. This system might also have a potential use for aiding in the distribution of fumigants in grain bins.

Attempts to achieve hermetic storage in underground and aboveground bins of shelled corn in Uruguay were not very successful in the earlier stages of a 5-year study. The project has ended, the bins have been unloaded, and some final data have been submitted. The results reported are quite variable. It appears that hermetic conditions were finally obtained in some bins where the oxygen content was low, the carbon dioxide was high, and at least some quality factors were maintained at a satisfactory level.

About 800 varieties of wheat from the World Collection were screened in India for resistance to attack by the rice weevil. Less than five weevils per test sample emerged from about 5% of the varieties. Of 300 varieties tested against the lesser grain borer, 5.6% showed resistance to attack.

2. Biology, Ecology, and Physiology. Laboratory tests showed that confused flour beetle adults preferred wheat containing 1 to 4% of cracked wheat or elevator dust over cleaned wheat. Also, 30 to 40% more progeny developed in wheat with 4% dockage than in cleaned wheat.

Tests with olfactory apparatus and organic solvent extracts of adults show the presence of a male attractant in female Angoumois grain moths. The extract on filter paper caused a premating response by males as strong as that caused by females. Virgin females were more attractive than mated ones to males, and they were most attractive 48 to 68 hours after emergence.

There has been no satisfactory way to study nutrition of the Angoumois grain moth because newly hatched larvae bore into kernels of grain and complete their development to the adult stage, completely hidden. A significant new finding is that larvae will readily enter and grow in kernel-size pellets made with various proportions of the nutrients found in whole wheat kernels. Thus for the first time we have a way to study the development of larvae in food media of known, controlled composition. The developmental period to adult emergence is about 35 days in wheat kernels. Preliminary explorations show that development required 140 days in a pellet made almost entirely of endosperm. When only 1% of germ was added the period was reduced to about 100 days. Further study with varied diets will be conducted. In another phase of work a true-breeding population of red-eyed Angoumois grain moths has been developed from the descendants of a rare red-eyed male and a typical black-eyed female. There are indications the trait is recessive. Further knowledge of the inheritance of the character could provide a valuable tool for other research. (Cooperative Agreement, Kansas State University)

Studies in India showed that khapra beetle larvae survived at 68°F., but there was hardly any growth. At 86°F. some larvae enter a quiescent stage or diapause but this did not occur at 95° and 98.6°F. Diapausing larvae showed a considerable increase in fat and glycogen content over that in normal larvae. The materials are stored as energy sources for diapause. Studies of the changes in these metabolites during transformation from pupa to adult showed a reversal of what happens during the initiation of diapause.

A 5-year study in Israel was concluded on the influence of environmental conditions on population dynamics of the khapra beetle. A few of the many findings are summarized as follows: (1) Microflora studies showed that the percentage of wheat infested with Alternaria drops after the khapra beetle lives in the wheat. However, the percentage of germ infested with Aspergillus flavus rises from 17.6 to 51.5 in wheat and from 12.5 to 86.6 in barley. The dominant fungus found in larval feces was A. flavus with A. fumigatus second, (2) the fungi have little or no direct effect on the life cycle of the beetle, but the fungi the insects spread cause an increase in grain moisture and temperature, both of which are beneficial to growth and longevity of the beetle, (3) it was found that the presence of feces in

food extended the length of the larval periods and induced diapause. Several substances known to exist in the feces were fed separately and high concentrations of allantoin, urea, and uric acid caused larvae to diapause, (4) water and petrol-ether extracts of feces were tested. The petrol-ether removed the substance causing diapause but the water did not, (5) of nine antibiotics tested, tetracyclin and tyrothricin had the greatest effect in prolonging larval life and inducing diapause. They were more effective at low concentrations than at high ones, (6) the information was published that crawling larvae leave a factor in their wake that attracts other larvae of the same species. In subsequent research these results could not be duplicated, therefore, a notice was published correcting the earlier report, (7) a substance produced by virgin male or female adult khapra beetles was found to attract both virgin males and females of the same species. The pheromone, therefore, functions as a congregating substance rather than as a sex attractant. It was found to repel adult red flour beetles, Tribolium castaneum, (8) marked photonegative responses were found in khapra beetle larvae. The negative response to light with short wavelengths was distinctly stronger than two long wavelengths. Ten different pairs of illumination combinations were tested and larvae preferred long wavelengths over short ones, with the exception that they preferred violet over blue, (9) adult khapra beetles also displayed a strong photonegative response. A higher proportion of females than males were found on the dark side both in single-sex and mixed-sex groups, (10) larvae and adults were both distinctly hygronegative in all gradients tested. Reactions were more pronounced in tests with groups than with individuals. When the antennae of adult males and females were removed they lost their ability to respond to moisture gradients. The investigators considered this as proof the hygrosensors are located on the antennae, a condition known to exist in some other stored-product insects, (11) sixteen manuscripts were prepared from results of this project and most have already been published.

3. Improved Pesticidal Control. Serious distributional deficiencies were found when wheat, corn, or grain sorghum at 60° F. or less were fumigated by gravity penetration in 9,000- or 12,000-bu. metal bins with an 80:20 mixture of carbon tetrachloride and carbon disulfide or a 75:25 mixture of ethylene dichloride and carbon tetrachloride. Test insects were used to determine the effectiveness of fumigation at the different grain temperatures. Air-gas samples were drawn from different locations within the grain mass at intervals through 3-day fumigation periods to determine by gas chromatography the concentration distribution of fumigant components throughout the grain at succeeding time intervals, as well as to determine the ratio of components existing at different times and locations. Rapid sorption of the carbon tetrachloride from the 80:20 mixture and the ethylene dichloride from the 75:25 mixture at low temperatures greatly reduced the effectiveness of the fumigations. It also created a definite fire hazard with the 80:20 mixture because of the increased carbon disulfide ratio as the gas moved down through the grain mass. The fire hazard would be even greater if the fumigant dosage were increased in an attempt to compensate for the decreased efficiency at lower temperatures.

When the 80:20 or 75:25 fumigant mixtures were applied to cold grain of 60° or less by the closed-recirculation method, acceptably uniform distribution and excellent mortality of test insects were obtained with dosages as much as 1 gallon per 1,000 bu. lower than those used for gravity fumigation. Component ratios of the 80:20 mixture were similar to the original throughout the grain mass. When the 75:25 mixture was applied, higher concentrations of the carbon tetrachloride than of ethylene dichloride were recorded in over 84% of the samples analyzed. Therefore the ratio of the gases as they reached the test insects was quite different than the 75:25 component ratio of the mixture as applied. This research shows that when grain temperatures are below 60° the 80:20 fumigant should be applied by closed-recirculation rather than by gravity penetration, and that this method should be used for the 75:25 fumigant below 70°F.

The effectiveness and persistence of newly-applied malathion in wheat were not altered by aeration at a normal air-flow rate and under atmospheric conditions of 80°F. and 60% relative humidity. A loss in effectiveness when aerated at 75% relative humidity could not be attributed directly to a loss of toxicant from the treated wheat on the basis of available residue analyses. These results and data from previous tests where it was not possible to correlate residue analyses and bioassay results, raise some questions that need investigation. (Exploratory)

Further tests with phosphine fumigation of processed cereal products in rail cars show that 165 aluminum phosphide pellets per 1,000 cu. ft. gives highly effective results in standing or rolling cars when proper procedures are followed. Two new techniques for applying the pellets were tested and found effective. In one method the pellets are crushed and in the other they are ground and the dust is blown into the cars. Both methods produce gas almost instantly instead of after 3 hours as with whole pellets. Attaining a lethal concentration of gas so promptly improves the efficiency of the fumigation operation. (Exploratory)

Studies on the effect of sublethal dosages of synergized pyrethrum on the rice weevil revealed that certain conditions of exposure increased rather than depressed the production of progeny. This is the first recorded evidence of such an effect. (Exploratory)

Phosphine was found effective as a space fumigant in a test conducted in pilot flour mill. The grinder-blower method of dispensing aluminum phosphide pellets was used. Another test showed that aluminum phosphide pellets could not be used successfully for the spot fumigation of unsealed flour mill machinery and equipment. (Exploratory)

Tests were conducted to study three factors that were believed might influence the deposition and distribution of malathion on bulk shelled corn when applied by the forced-ventilation of aerosols. It was found that grain temperature was not as important a factor as aerosol particle

size and rate of airflow. Complete mortality of test insects was obtained at depths of 14 feet of grain when aerosol particles of 0.4 micron mass median diameter were moved through the grain with an airflow rate of 0.3 cubic foot per minute. (Exploratory)

Bay 77488 was more effective at 5 ppm on wheat than was malathion at 8 ppm against rice weevils, cigarette beetles, and confused flour beetles in small-jar tests after aging 6 months. These insects did not infest the wheat treated with Bay 77488 but some of each species survived and reproduced in the malathion-treated wheat. The Bay compound is of particular interest because of its extremely low toxicity to warm-blooded animals.

4. Toxicology of Pesticides. A five-year study in Israel on the effect of ethylene dibromide (EDB) on farm animals has been completed after the development of much valuable information. Some of the results have already been published in ten papers in scientific journals and at least four others will follow. EDB is a component of several fumigant mixtures commonly used in this country to control insects in grains, foods, and animal feeds. About 10 years ago it was found that EDB in poultry feed would reduce the size and number of eggs laid, and a little later that high amounts would stop egg production irreversibly. This raised serious questions about the possible effect of EDB on the reproductive system of farm animals. The research in this project has provided at least partial answers to many important questions. Areas of hazard are delimited and conditions for the safe use of EDB have been defined. Some specific findings are summarized as follows: (1) residue analyses were made in several grains, oil seeds, dried and fresh fruits, vegetables, and feed and the amount of EDB present was recorded immediately after fumigation and at periods up to 70 days. Residue analyses at different times after fumigation were also made on carbon tetrachloride, carbon disulfide, chloroform, and trichloroethylene, all compounds that are used in fumigant mixtures with EDB. (2) It may be necessary to aerate feed for laying hens 30 days or more after EDB fumigation to bring the residue down to a level that will not affect egg production. Careful attention must be given to proper aeration. (3) Pertinent to a new German food law banning any carbon tetrachloride residues in grain, under some test conditions fumigated grains contained about 3 ppm after 1 week of aeration, 2 ppm after 2 weeks, 1 ppm after 6 weeks, and 0.5 ppm after 10 weeks. (4) A simple test was developed that permits non-technical personnel to detect EDB in fumigated commodities down to a level of 15 ppm. (5) Laying hens were the most susceptible to toxic action of EDB of the various laboratory and farm animals studied. Ten ppm of EDB in the mash is the upper limit to avoid adverse effects. This corresponds to about 1 mg/kg daily intake. Even this amount in prolonged feeding may cause reduction of egg size. (6) Bulls fed 2 mg/kg of body weight of EDB daily developed abnormal spermatozoa after 2 weeks. This amount of EDB would be equivalent to about 100 ppm in the grain or feed concentrate of an animal weighing 1,100 pounds and fed 22 pounds of concentrate per day. This concentration would be present only in mash containing unaerated grain and aeration for 3 to 7 days after fumigation would reduce the residue to a safe level of 50 ppm or less. (7) Rats and cockerels were not sensitive to as much as 200 ppm of EDB in the total diet as far as growth, feed consumption, sexual development, and general

health were concerned. (8) Calves a few days old were seriously affected by 10 mg/kg of EDB daily and died after a few weeks. A dose of 40 mg/kg daily was lethal after 2 days. (9) Doses of 2-3 mg/kg of EDB daily caused no observable detrimental effects on milk cows, calves, or yearling sheep. (10) Extensive biochemical and toxicological studies developed a great deal of information on the mechanism of acute poisoning by EDB and on its metabolites. A theoretical detoxification mechanism has been proposed. A significant contribution has been made to the knowledge of the toxicology of EDB.

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RICE - MARKET QUALITY
Market Quality Research Division, ARS

Problem. Harvested rice is subject to damage or deterioration in quality while in marketing channels through normal metabolic changes, by the action of disease organisms, and by insect infestation. There is need for developing more effective ways of preventing insect infestation during storage, handling, processing, packaging, and transportation of rice. Attention must be given to finding control methods that will minimize or eliminate pesticide residue hazards. To maintain the quality of rice, more precise information is needed on the changes that occur in handling, storage, and transportation. To insure uniform and standardized products and more equitable prices to all concerned, new and improved procedures for measuring quality factors must be developed for use in inspection, grading, and standardization operations.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving engineers, chemists, and plant pathologists in basic and applied research on the quality evaluation and quality maintenance of rice. This work is located at College Station, Texas, in cooperation with the Texas Agricultural Experiment Station.

The Federal scientific effort in this area totals 2.0 scientist man-years: quality evaluation 1.0 and quality maintenance 1.0.

A grant to the Department of Plant Chemistry, Valencia, Spain, provides for a study on storage changes in milled rice and their relation to market quality. Its duration is for 4 years, (1964-68) and involves P.L. 480 funds with a \$62,479 equivalent in Spanish pesetas.

A grant to the National Institute of Hygienic Sciences, Tokyo, Japan, provides for a study covering the cause and development of mycotoxins in rice as a result of invasion and growth of fungi during postharvest conditioning, handling and storage. Its duration is 3 years (1965-68) and involves \$33,164

A grant to the Central Food Technological Research Institute, Mysore, India, provides for a study covering the control of microflora and related production of mycotoxins in stored sorghum, rice and groundnuts. Its duration is 5 years (1966-71) and involves P.L. 480 funds with a \$106,533 equivalent in Indian rupees.

There is also a Departmental program of entomological research on the prevention and control of insect infestation in rice in the marketing channels. It was formerly headquartered at Fresno, California, but was inactive this year. Just before the end of the reporting period the project was transferred to Beaumont, Texas, and a new research entomologist was employed for assignment to the investigations. A cooperative agreement was signed with the Agricultural Experiment Station of Texas A&M University for the operation of this project. Approval was obtained for the erection of a \$45,000 building to house the research, and construction has begun on the property of the Rice-Pasture Research and Extension Center at Beaumont. Much of the cross-commodity research reported in Area 13, "Insect Control in Marketing Channels," is applicable to the problems in rice.

A grant to the Tokyo University of Agriculture, Tokyo, Japan, is for a 3-year study, part of which is on the constituents of rice that attract insects. It continues until August 1968 and involves P.L. 480 funds with a \$38,622 equivalent in Japanese yen.

Line Project MQ 1-9, a study of gas fired infrared rice dryers for insect control, was terminated in September 1966.

PROGRAM OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 2.7 scientist man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement and evaluation of quality

1. Degree of Milling and Color of Rice. The Rice Ratiospect, an instrument for measuring degree of milling, color and degree of parboiling, was field tested in the Rice Inspection Office, Consumer and Marketing Service, Houston, Texas. Meter readings corresponding to various official grades now in use were established by measuring type samples. A high correlation of meter readings versus visual grades was obtained except for samples containing large amounts of broken kernels. A similar field test was begun at a commercial mill to determine the feasibility of using the instrument for control of degree of milling.

B. Quality maintenance in conditioning, handling and storage

1. Microbiological, Chemical and Physical Deterioration of Rough Rice. Rough rice stored under optimum or near optimum conditions for the development of storage fungi showed a cyclic increase and decrease in the rate

of respiration. The cyclic phenomenon has been measured with rice sterilized and not sterilized before inoculation with spores of the Aspergillus flavus group. Visual observations indicate that heavy spore formation accompanies the increased rate of CO₂ evolution.

2. Storage Changes in Milled Rice. Large differences between different layers of the rice kernel were found in individual sugars, soluble protein fractions and amino acid composition, enzyme activities (alpha-amylase, beta-amylase, proteases, lipoxidase, and lipase) and stability of lipids. Storage for 10 months caused no change in total lipid content but free fatty acids increased whereas neutral fats and phospholipids decreased. Quantitatively, these changes were greater in the outer layer of the kernel.

The procedure previously developed to determine the content of sulfhydryl and disulfide groups (SS and SH indices) has been applied to 13 varieties of rice and a highly significant correlation has been found between the SS index and quality (as determined organoleptically).

3. Mycotoxins in Rice. A cooperative study with the Transportation and Facilities Research Division at Beaumont, Texas, of the effect of environmental factors on the development of aflatoxins in stored undried rice on a pilot-sized scale was continued with the 1966 crop. Moisture contents in excess of 20% (wet basis) were shown to increase greatly the probability of aflatoxin contamination when other primary controlling factors, such as ambient temperature and extent of aeration, are favorable for the production and accumulation of the toxins.

The distribution of aflatoxin in the rice kernel was shown to vary with the stage of development of Aspergillus flavus infection. Thus, the milling process can be expected to remove toxin in contaminated brown rice.

Five hundred and seventy-five of the Penicilli and Aspergilli isolated from 219 samples of milled rice in Japan were identified to species level. The predominant Penicilli were the Penicillium canescens, P. cyclopium and P. citrinum series. The Aspergillus glaucus and A. restrictus groups of the Aspergilli were most prevalent.

Out of a total of 113 strains of fungi, 51 of which were isolated from rice, only 2 strains of the A. flavus group could be demonstrated to produce aflatoxins. The two strains were isolated from flour and constitute the first report of aflatoxin-producing fungi isolated from foodstuffs in Japan.

C. Prevention of insect infestation

1. Biological and Physical Control. Isolation of the insect-attractant material from polished rice by steam distillation was not successful. Isolation by nitrogen aeration gave a very small yield. Solvent extraction was successful with methanol, ether, acetone, normal hexane, and water. Ether appeared to be most suitable. The attractant has been extracted from the concentrated ether extract into a water solution at 70° C. in a rotating agitator. This water extract displayed a strong luring activity for rice weevils and had a pH value of 3.9. The water extract was evaporated in vacuum and the distillate fraction was highly attractive. The residual liquid was treated with a saturated sodium bicarbonate solution, then treated with sulfuric acid and ether to separate out another attractant fraction, acid in nature. Yield of the two crude attractants is estimated at less than 30 mg. per kilo of polished rice. Study of the two fractions is now being made with thin-layer chromatography and gas chromatography. Isolation of two attractant fractions from rice bran has also been made.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Objective Measurement and Evaluation of Quality

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Prevention of Insect Infestation

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FEED AND SEED - MARKET QUALITY
Market Quality Research Division, ARS

Problem. Many methods of determining seed and feed quality currently in use require too many man-hours, impose tedious work on the analyst, are incapable of high degrees of standardization, and do not provide accurate indices for quality. Practical methods are needed for determination of such quality factors as mechanical purity, genetic purity, germination, vigor, weed seed content, protein content (of feeds) and infection with disease organisms. The deleterious effects of high temperatures and relative humidities on stored seed are well known but little is known about the part played by storage molds, especially the minimum temperature-relative humidity combinations under which the storage molds survive in stored seed. There is urgent need to increase basic research which would serve as a basis for developing more practical methods of determining seed and feed quality and for recommending improved practices of storing seed.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-time program on seed and feed research involving botanists, plant physiologists, plant pathologists, engineers, and chemists engaged in both basic and applied research on quality evaluation and quality maintenance of seed. This research is conducted at Beltsville, Maryland, and College Station, Texas, and by research contract with the Oregon Agricultural Experiment Station and Analtech, Inc., Wilmington, Delaware, and by cooperative agreement with Mississippi State University.

The Federal effort in this area totals 7.75 scientific man-years: quality evaluation, 6.25, and quality maintenance, 1.5.

A P.L. 480 grant with the Instituto Biologico, Sao Paulo, Brazil, provides for a study of substrate moisture levels for germination testing of agricultural seeds. The project ran from 1961 to 1966 and involved \$31,016 equivalent in Brazilian cruzieros. This project was terminated during the 1967 fiscal year.

A P.L. 480 grant with Rijksproef-station, Wageningen, Netherlands, provides for a study of the health condition of seeds in commercial channels and development of methods suitable for routine testing for seedborne organisms. The duration of the project is five years, beginning 1963, and the total grant in Dutch guilders is the equivalent of \$55, 918.

A P.L. 480 grant with Samenprufstelle, Munster, Germany, provides for a study of the biological and environmental factors affecting the physiological maturity of grass seeds. The duration of the original project was for three

years, beginning April 1965, and the total grant in German marks was the equivalent of \$31,775. An extension of two additional years and an increase in the grant of \$22,675 equivalent has been approved.

A P.L. 480 grant with Forschungsgemeinschaft fur Saatgutforschung, Reutlingen, Germany, provides for a study of methods for maintaining the germination of seeds in storage and in trade channels. The project has a duration of five years, beginning April 1965, and the grant in German marks is the equivalent of \$52,338.

A P.L. 480 grant with the Agricultural Research Station, Beit Dagen, Israel, provides for research to find a satisfactory invisible marker of seeds in commercial channels and for research purposes. The project runs for three years, beginning February 1965, and the total grant in Israeli pounds is the equivalent of \$45,640.

A P.L. 480 grant with the Indian Agricultural Research Institute, New Delhi, India, provides for a study to evaluate the X-ray technique for detecting empty seeds in purity testing and for determining seed viability. Its duration is five years, beginning October 1965, and the total grant in Indian rupees is the equivalent of \$37,464.

A P.L. 480 grant with the Weizmann Institute of Science, Rehovoth, Israel, and the Hebrew University, Jerusalem, Israel, provides for research to isolate and determine the structure of germination inhibitors in seeds. The project runs for three years, beginning October 1964, and the total grant in Israeli pounds is the equivalent of \$50,722.

A P.L. 480 grant with the Israel Institute of Technology, Haifa, Israel, provided for a study to develop tests for nutritive value of cereal grains and feeds. The duration of the original grant was 4 years (1961-65) and an extension of 1 additional year was approved, making the completion date June 1966, but no final report has been received. The total grant involved an expenditure of \$53,298 equivalent in Israeli pounds.

The following project was terminated during this period: "Microbiological determination of grass seeds during marketing"

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 3.6 scientist man-years is devoted to this area of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement and evaluation of quality

1. Development and Standardization of Seed Testing Equipment. A new seed blower using the Venturi principle was designed and constructed. A semi-automatic sample divider designed to extract from the sample received an exact quantity of seed for a working sample was designed and constructed. A torsion balance and a photoelectric switching circuit are incorporated into the model machine.
2. Seed Metabolism. The process of polysome formation, which had been previously shown to occur within 15 minutes after exposure of embryos to water, was studied with tobacco mosaic virus RNA. It was established that the process requires ATP, ribosomes and at least two supernatant components.
3. Determining the Purity of Certain Grass Seeds. Additional tests conducted to determine the toxicity of certain low surface tension solvents suitable for use with the flotation method of purity analyses of grass seed led to the discovery of interactions which occur when two or more solvents are mixed, some of which are beneficial. Reports from other researchers show the accuracy of the flotation method compares favorably with the official method for little bluestem (Andropogon scoparius) and big bluestem (A. gerardi). Purity analysis can be made by the flotation method in only one half of the time required by the official method.
4. Development of Seed Germinator. An automatic condensate evaporator was designed and constructed to overcome the problem of drying out of substrate materials.
5. Processing Grass Seed for Laboratory Testing. Tests of a modified blender to separate multiple florets into single florets showed this device to be inadequate because of insufficient separation or excessive damage to the seeds. Various laboratory machines which can be used or modified to efficiently remove awns or other undesirable appendages will be investigated.
6. Seed Vigor. Specific recommendations for a respiration test for corn seed vigor were published in the AOSA Proceedings. The respiration test was also found to be useful for detecting loss of pea seed vigor due to mechanical damage during combine harvest and for determining seed quality of acid-delinted cotton and snap bean seeds. Respiratory measurements only 60 minutes after wetting barley can distinguish between vigorous and non-vigorous lots. Seeds of corn, wheat, sorghum and radish given growth-inhibiting doses of gamma irradiation were distinguished from non-irradiated controls by measuring respiratory rates and determining the respiratory quotients in an atmosphere of 100% oxygen during the first 6 hours of germination. Studies on lettuce seeds before and after exposures to red (germination stimulating) and far-red (germination inhibiting) light indicated that changes in respiration occur 2 to 3 hours after the application of the light treatments.

7. Protein Content of Feed Grains. A technique was developed for predicting protein content in varieties of grain sorghums by measuring the change in reflectance readings taken before and after water addition. The change in reflectance readings for a given variety was directly related to its protein content.

8. Verification of Varietal Designations of Crop Seeds. A seed protein variant was discovered in soybean varieties. All varieties tested had either type A or type B protein but none had both. The inheritance of the variant was established by using three parental crosses and their respective F_1 , F_2 and F_3 selfed progeny. The evidence clearly indicates a simple Mendelian ratio involving two codominant genes operating at a single locus. Only a few genetic systems involving plant proteins have been described to date. Specific morphological growth patterns have been determined for certain varieties of soybeans which should aid in distinguishing and identifying these varieties.

9. Detection and Identification of Seedborne Pathogenic Fungi. The reflectance of visible light from conidia of one isolate each of twenty species of *Aspergillus* was measured over a range of 440 to 700 nm. Reflectance curves produced by the conidia of a number of species were sufficiently far apart to serve as a means of identifying the taxa. Large numbers of isolates of each species will have to be studied before a practical method can be developed.

10. Temperature and Light Effects on Seed Germination. Upon completion of the thermogradient plate, an experiment was conducted with four inbred lines of corn and various crosses. The hybrid seed germinated over a broader span of temperature than did seed of the inbred parents in the same period of time. Possibly this type of expression might be used to quantitate hybrid vigor.

Two types of light responses in seeds of many ecotypes of *Eragrostis curvula* were verified: (1) high germination in response to light after a favorable dark-imbibition period and (2) lowered germination when light was applied during the early hours of darkness.

11. Predicting the Longevity of Seeds in Storage. An accelerated aging test was developed in which seeds are placed at a high temperature and humidity for a brief period and then tested for germination. Preliminary results with a number of field and vegetable crop seeds indicate that the accelerated aging test has good potential of predicting the storability of seed lots.

12. X-rays and Radiograms of Aids in Analyzing Seeds. Radiograms of wheat, barley, corn cucurbits, rice and other crops revealed the extent of embryo and endosperm development as well as the presence of broken, shriveled, damaged and empty seeds. The presence of insects inside seeds can be detected by X-rays and in some instances identification can be made.

13. Germination Inhibitors in Seeds. Methods have been developed for the extraction, isolation and characterization of phenolic germination inhibitors from barley. Catechuic aldehyde was identified for the first time in barley and found to be a potential inhibitor of lettuce seed germination. Two other new germination inhibitors, syringaldehyde and protocatechualdehyde, were isolated from the seed coats of barley.
14. Invisible Marking of Seeds. Ferric and ferrous compounds were found to be most promising as seed markers, especially ferric citrate, but different stains had to be used for the various types of seeds.
15. Biological Basis of Physiological Phenomena in Seed Germination. The first 6-month report indicates two contrasting patterns of increase in enzymatic activity in germinating pea seeds.
16. Factors Affecting the Physiology of Grass Seeds. Seeds of Kentucky bluegrass and orchardgrass harvested in the early dough stage, showed lower germination than those harvested in the late dough or ripe stages. In orchardgrass and annual ryegrass, dormancy was more of a problem in the seeds harvested in the immature stage. Alternating temperatures and gibberellic acid were more effective in improving the germination of Kentucky bluegrass than that of timothy, meadow fescue, orchardgrass or annual ryegrass.
17. Routine Testing Methods for Seedborne Organisms. A modified blotter test for seed "health" testing was developed. The key principle lies in damaging or killing seeds or seedlings to be tested for seed-borne fungi, resulting in stimulating growth of certain seed-borne fungi. Initially, killing was done to control germination of the seeds and seedlings by application of 2,4-D. Upon finding that the 2,4-D stimulated growth of fungi, the principle was extended to killing the seedlings by freezing at -20°C . Specific test procedures for a number of fungi on seeds of different crops were worked out.
18. Moisture Levels for Seed Germination. Maximum germination was found to occur over a range of moisture levels of the substratum rather than at a specific level.

B. Quality maintenance in storage

1. Deterioration of Grass Seeds in Storage. Efforts were made to produce seeds of annual ryegrass under sterile conditions for use as germ-free controls.

Little progress has been made in sectioning seeds to get thin slices for microscopic study. Because of the hard, brittle nature of the seed, the sections break easily.

2. Preserving the Germination of Seeds. Desiccation of seeds over quicklime follows a similar pattern regardless of species. The first third of moisture was lost within 2 days, the second third within 2 weeks and loss of the remainder required several months. Moisture (vapor) loss and uptake were different in legume seeds with hard seed coats. The rate of loss was fast at first and then gradual over a long period of time. Even though water vapor penetrates the seed coat, the rate of uptake is so slow that germination cannot proceed in a normal manner. The best vapor barrier for seed packaging materials was found to be a bag with aluminum foil between the double walls of paper (this was previously found by American researchers).

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Quality Maintenance in Storage

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MARKETING FACILITIES, EQUIPMENT AND METHODS
Transportation and Facilities Research Division, ARS

Problem. Differences in varieties of individual field crops and in the environments of producing areas where they are conditioned and stored, together with advancing techniques in cultural and harvesting practices, require new or modified marketing facilities, equipment, and methods. Such changes are essential to the efficient and economical handling, conditioning, and storing of these crops and to maintaining their quality. There is a need for improved designs for facilities based on functional and structural requirements, which will expedite the movement of commodities into, within, and out of the facility. There is also a need for handling and conditioning equipment which will minimize labor and other costs and also minimize the extent of physical damage (breakage) to the grain as it is handled into, within, and out of marketing facilities. More knowledge is needed of the relative efficiency of various handling and conditioning methods so that improved or revised methods and equipment can be developed to perform necessary operations.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving engineers engaged in both applied and basic research on, as well as application of known principles to, the solution of problems of handling, storing, and conditioning field crops in marketing channels. Grain aeration and drying research is carried out at Manhattan, Kans., on corn, wheat and grain sorghum and at Lafayette, Ind., on corn, in both laboratory and pilot-scale facilities and in commercial storages; in cooperation with the Agricultural Experiment Stations of respectively Kansas and Purdue University (Indiana), the Market Quality Research Division, and with grain storage firms; and is supplemented by a research grant by the Corn Industries Research Foundation made through Purdue University. Investigations designed to determine the extent and causes of physical damage (breakage) to grain by handling equipment used in marketing facilities are conducted at Manhattan, Kans., in cooperation with the Kansas Station; and are supplemented by a research contract with Cargill, Inc., Minneapolis, Minn. Investigations on the basic theory of dynamic and static pressure phenomena in grain under storage conditions, by theoretical analysis and simulation, are conducted under a research contract with Dr. J. D. Isaacson, St. Louis, Mo. Studies to develop improved techniques and equipment for uniformly blending lots of seed are conducted under a research cooperative agreement with the Mississippi Agricultural Experiment Station, the Consumer and Marketing Service, and the Field Seed Institute of North America. Studies on the handling, drying, aerating, and storing of rice are conducted at Beaumont, Tex., in cooperation with the Texas

Agricultural Experiment Station, the Market Quality Research Division, and at commercial facilities in Texas, Arkansas, Louisiana, and Mississippi.

The Federal effort devoted to research in this area during the Fiscal Year 1967 totaled 10.9 scientist man-years; 3.7 to grain aeration, storage and drying; 4.1 to the effect of handling equipment and methods on extent of physical damage to grain; 1.4 to the handling, drying, aerating, and storing of rice; 0.7 to the basic study of grain pressures; 0.2 on uniformly blending seed lots; and 0.8 to grain transport equipment.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Drying, Aerating, Storing and Handling Rice

1. Drying. At Beaumont, Tex., tests using a pilot-size continuous-flow heated-air dryer were conducted to determine the effect of various velocities of air heated to 115° F. on the rate of drying, milling yield of rice, and fuel and power requirements. Air velocities tested ranged from 102 to 167 f.p.m. at the point where the air entered the rice. Results indicated that the highest air velocity increased the drying rate by one-third with no significant decrease in milling yield, but at the expense of an increase in fuel and power requirements. This increase in drying rate was confirmed by laboratory-scale tests where the rate increased 100 percent when the air velocity was changed from 3.3 to 42.5 feet per minute. Results of other tests showed that the change in milling yield of the rice was inversely proportional to the final rice moisture content within the 10-14 percent moisture contents tested. The amount of head rice generally increased 1 percent when the final moisture content of the rice was decreased 1 percentage point.

2. Aeration and Storage. At Beaumont, Tex., the study of using aeration for maintaining the quality of undried rice was continued. Batches of green rice were stored for 21 days and sampled periodically. Quality tests of samples included a determination of grade by C&MS Grain Division personnel. Rice at three different initial moisture contents was stored simultaneously with all bins aerated at a rate of 1 c.f.m. per barrel. Rice moisture contents were approximately 24, 22 and 20 percent (wet basis). Relatively large amounts of aflatoxins were found in rice stored at the high (24 percent moisture content) during warm weather. No significant amount was detected in rice going into storage at 20 percent moisture content during warm or cool weather. Rice having an initial moisture content of 24 percent was stored for 10 days during cool weather before detectable amounts of aflatoxin were found. When aflatoxin was detected in a sample a high percentage of rice kernels was infected by molds. This high percentage of infection was not necessarily accompanied by a large amount of aflatoxin. In general, rice samples which graded U. S. No. 1 were free of aflatoxins, although significant amounts were detected in a few of these samples.

3. Handling of Rough Rice at Commercial Dryers. Studies of operating methods, labor utilization, conveying machinery and company records were made at three commercial rice dryers in Texas and Louisiana during the 1966 harvest season. Rice drying costs; including amounts for labor, gas, electricity, depreciation, taxes, insurance and interest; averaged \$0.35 per barrel of rice dried by a new plant drying a large volume of rice as compared with \$0.76 per barrel for an older plant handling a smaller volume. Studies indicated that conveying equipment operated at less than full capacity at all three dryers. Improved utilization of equipment was obtained by using photoelectric relays to warn operators of an impending choke-up, ammeters to indicate the proper loading of conveyor motors, and a bypass on scalperators to divert part of the rice directly to a drying unit. Sampling selected lots of rice before and after dryer passes indicated these three drying plants were successful in maintaining the milling quality of rice although one plant used the dryeration process while the others tempered rice at a high temperature.

4. Bulk Handling of Milled Rice. Tests were continued to determine the amount of breakage resulting from dropping (free fall) bulk milled rice from different heights. In general, as the height of free fall increased up to 60 feet, the amount of breakage increased. Medium-grain rice was more resistant to breakage than long-grain rice. More breakage resulted from dropping rice on a flat steel surface than on a flat concrete surface or on a layer of rice. Inclining the steel surface 45 degrees reduced the amount of breakage. Rice at a moisture content of 13 percent was more resistant to breakage than rice at 11 percent. The amount of breakage increased slightly when rice of 11 percent moisture content was dropped through air of 50 percent relative humidity as compared with rice dropped through air of about 100 percent relative humidity. Rice temperatures in the range between 30° F. and 80° F. had no effect on the amount of breakage when rice was dropped through air having a temperature of 62° F. and relative humidity of 88 percent.

B. Grain Aeration and Drying

1. Aeration. At Manhattan, Kans., field studies on aerated flat-type steel grain storages are now complete. All of the grain was loaded or transferred out of these storages by the cooperators.

Grain sorghum was stored in a 100-foot wide flat-storage for four years at Hastings, Nebr. This storage was equipped with an aeration system using lengthwise ducts and fans that provided adequate air distribution through the 16 to 30 feet of grain depth. The mixed and loaded grain sorghum was officially graded No. 2. Grain sorghum taken from the center peaked surface to the two-foot depth was sample grade due to musty and damaged kernels. Fatty acid content of the sample-grade grain ran from 80 to 150 values, while the No. 2 grain ranged from 60 to 80 values. A second storage, 60 feet wide, was observed during an hour's unloading operation of the grain sorghum which had

been stored in place for 10 years. This grain was in good condition except for about 18 inches of the surface layer which graded "sample" as a result of moisture migration and high temperatures from summer heat.

At Sterling, Kans., 500,000 bushels of wheat stored in a 140-foot wide by 160-foot long flat storage for 8 1/2 years were in uniformly good condition when unloaded. All of the grain was old crop wheat when the storage was filled in 1958. The averages of five samples taken during unloading were as follows: Test weight 61.1 lbs./bu.; moisture content 10.5 percent; protein 13.25 percent; sedimentation test value 35.8; germination 5.0 percent; and fat acidity 67.5 (mg. KOH per 100 g. dry basis).

Studies were continued on the effectiveness of a two-fan, crossflow, ventilation system (as described in ARS 52-20) for conditioning wheat and grain sorghum. At Abilene, Kans., a test bin was filled with wheat which averaged 11.1 percent moisture content. However, the bin also contained a layer of 500 bushels of 18-19 percent wheat. After 5 days with no fan operation, the temperature of this wet layer increased 9° to 109° F. Fan operation reduced this temperature to 88° F. in 28 hours. Again with no fan operation, the wet layer increased to 111° F. in 2 weeks. The fans were restarted and the temperature lowered to 82° F. in 24 hours. Samples of wheat obtained during unloading at the end of 5-week storage tested 11.2 percent moisture. In another test results of operating a crossflow system on newly harvested grain sorghum showed the initial grain sorghum moisture content of 14.7 percent was reduced to 13.8 percent. Fan operation was continuous for 29 hours in October, and 30 hours in both November and in December. During this time the initial grain sorghum temperature of 64° was reduced to 31° F.

The study to determine the effect of ambient air temperature on the temperature of wheat in static (unturned) storage was completed. The wheat, stored in a concrete upright storage (18 feet in diameter and 110 feet high) was unloaded in July after a 29-month storage period. Results indicate that although the wheat was marketed in good condition, initial germination of 63 percent was reduced to 27 percent and initial fat acidity of 27 was increased to 69. Analysis of the transient heat transfer in this bin is continuing, pointing to a prediction equation for wheat temperatures at a given location in a bin.

2. Drying. At Lafayette, Ind., the results of the mathematical simulation and laboratory testing of the basic methods of exposing grain to air heated to temperatures in the range of 200°-400° F. were summarized and two manuscripts prepared. Comparison of the three drying methods - crossflow, counterflow and concurrent flow - showed the highest moisture removal rate per foot of grain bed depth using the counterflow method. Concurrent flow drying produced corn of slightly higher quality than the other two methods. The crossflow method overdried the grain on the air input side and underdried it on the air exhaust side. The mathematically developed drying models predicted (with acceptable accuracy) the performance of each of three basic dryer designs. The final

moisture contents predicted for concurrent flow drying averaged only 0.5 percentage points below those obtained in laboratory tests in a model dryer. With the aid of a high-speed digital computer it was possible to study dryer performance over a range of variables that would be difficult and time consuming to duplicate in field or laboratory testing.

The study was continued on determining the effect of heat drying on the equilibrium moisture content (EMC) of corn. Shifts in the whole kernel EMC were again shown to be related to the severity of the drying treatment. Evaluation of the EMC of the physically separable parts of the corn kernel is not complete. Partial results indicate that heat drying may shift the EMC of some of the kernel fractions more than others.

Comparison of upward and downward airflow for cooling batches of hot corn accumulated from a continuous flow heated-air dryer showed fewer problems from the condensation of water vapor when downward air movement was used. With upward airflow there was more wet corn next to the bin walls and at the corn surface. Although there are some operational advantages and a 4-6 hour saving of time per batch if upward airflow is used, the corn should be moved after cooling. The resultant mixing of the wet and dry corn during moving eliminates most of the problem associated with moisture accumulation. If the corn is stored in the bin where it is cooled, downward movement of the cooling air is recommended. A downward flow rate of only 0.1 c.f.m. per bushel was satisfactory in a bin insulated with 1" of polystyrene foam.

The storage of field-shelled corn at 22-23 percent moisture under aeration and refrigeration was only partially successful. Intermittent aeration with outdoor air at temperatures between 35° and 45° F. resulted in 94 percent of the seeds becoming infected with Penicillium after 22 weeks of storage. Where the interseed air was circulated through a refrigerator to maintain corn temperatures between 40° and 50° F., a similar mold invasion occurred in only 8 weeks of storage. Of the treatments used, the best storage conditions were maintained by continuous ventilation with outdoor air. The moisture content of this corn was reduced more rapidly than that in the other tests and reached an average of 16.2 percent after 20 weeks and 13 percent after 33 weeks. The aeration airflow rate in all tests was approximately 0.6 c.f.m. per bushel.

Laboratory tests were conducted on the blending of corn of different moisture levels to yield an average moisture content of 15 to 15 1/2 percent. When the spread between the moisture levels of a 50-50 blend was 10 percent (percentage points), a difference of 2.7 percent persisted after 20 days of storage at 5° C. At 25° C., the difference was 1.3 percent after 20 days. When the initial difference in moisture levels of the blends was 5 percent, the moisture

difference after 20 days was 1.6 percent and 0.7 percent under 5° and 25° C. storage. Thus, moisture equalization was reached faster at 25° than at 5° C. Also, the nonuniformity of the final moisture content increased as the spread increased between the moisture levels of the lots blended. Aeration at approximately 2 c.f.m. per bushel failed to increase the rate of moisture equalization or reduce the final spread in moisture content.

C. Effect of Handling Equipment on Physical Damage to Grain

1. At Minneapolis, Minn., tests are being continued under a research contract with Cargill, Inc., to determine the extent and causes of physical damage (breakage) to grain by handling equipment used in commercial facilities.

Tests were conducted to determine the amount of breakage occurring during the handling of wheat having a minimum temperature of 75° F. as compared to wheat having a maximum temperature of 50° F. In every test, the breakage was less in the higher wheat temperature range. This is illustrated by the following summary of test results with a grain thrower operating at a belt speed of 4,030 f.p.m. and at a distance of 10 feet from a vertical wood bulkhead:

Wheat kind	Wheat moisture Percent	Mean Breakage		Breakage decrease as percentage of 50° F. values Percent
		50° F. max. Percent	75° F. min. Percent	
Spring	10.5-11.5	0.27	0.15	44.5
Winter	10.5-11.5	0.22	0.07	68.2
Spring	12.5-13.5	0.14	0.08	50.0

The amount of breakage occurring in yellow corn was many times that occurring in wheat under the same test treatments. The following table compares the average maximum breakage resulting when yellow corn and wheat was discharged through a 12-inch diameter orifice and dropped 100 feet in free fall onto a concrete surface:

Grain <u>1/</u>	Grain moisture Percent	Breakage per each of 4 replicated test runs			
		1 Percent	2 Percent	3 Percent	4 Percent
Corn	12.5-13.5	12.0	13.6	10.6	7.8
Winter wheat	10.5-11.5	0.2	0.2	0.1	0.1

1/ Same grain at 50° F. used for each replicated test run.

Tests conducted to date indicate that the diameter of the grain discharge orifice, and thus the size of the falling grain stream, has an effect on the amount of breakage occurring during free fall. The following table compares the breakage of yellow corn with soybeans resulting from discharging them through a 12-inch and an 8-inch diameter orifice to fall free 100 feet onto a flat concrete surface:

Grain	Moisture	Temperature	Mean breakage with orifices-		Breakage decrease as percentage of 8-inch orifice values
	Percent		8-inch	12-inch	Percent
Corn	12.5-13.5	50 max.	13.8	11.0	20.3
Soybeans	12.5-14.0	40-65	2.2	1.4	35.8
Soybeans	10.5-11.5	40 max.	5.6	2.5	55.1

Tests completed to date indicate that the amount of breakage resulting from handling soybeans is considerably lower than corn but higher than wheat. The maximum breakage in pea beans was 13.65 percent when discharged through an 8-inch diameter orifice and dropped 100 feet in free fall onto a concrete surface. Further tests will be conducted with pea beans to determine handling treatments that will hold the amount of breakage to a desirable minimum.

2. At Manhattan, Kans., laboratory analyses were continued to determine the initial quality of grain samples obtained in tests conducted by Cargill, Inc. under a research contract. Each analysis included determinations of percent of internal kernel cracks, bulk and true density, porosity, percent broken by sieve operation and susceptibility to breakage. Representative samples of wheat were divided and tested for breakage both at Manhattan and Beltsville. Statistical analysis of the data indicated the results obtained at the two laboratories were not comparable.

Results of a study of the effect of moisture content on the bulk density of Hard Red Winter Wheat showed that drying or wetting the wheat had little effect on its bulk density. However the amount of dry matter varied linearly with moisture content.

Two varieties of Hard Red Winter Wheat at 9.1 to 10.5 percent moisture content were tested for internal damage that occurred prior to harvest. From 0 to 37 percent of the kernels from field handcut samples were damaged, compared to from 1 to 55 percent of the kernels harvested by combine. Analysis of results showed a significant effect of wheat variety, location grown and method of harvesting. Two varieties of grain sorghum ranging from 12 to 16 percent moisture content also were tested in the same manner. Results showed 0 to 3 percent of the kernels examined from handcut samples and 1 to 13 percent of the kernels from combined samples were damaged. Statistical

analysis indicated the method of harvesting and the interaction of variety and location significantly affected the number of kernels with internal damage.

The study on the effect of repeated wetting and drying on the internal cracking of winter wheat was completed. A manuscript covering the study is now being prepared. Analysis of results indicate that, when wetting the wheat to about 20 percent moisture content then drying it to 12 percent using various air temperatures, increasing the number of cycles increased the number of multiple cracks but decreased the number of single cracks in the wheat. Although increasing the temperature increased the number of internally cracked kernels, this effect was less pronounced than the effect of the number of drying cycles.

D. Dynamic and Static Pressure Phenomena in Grain Under Storage Conditions

At St. Louis, Mo., investigations on the basic theory of dynamic and static pressure phenomena in grain under storage conditions are being conducted under a research contract with Dr. Joel D. Isaacson. Theoretical analysis, applied mathematics, analytical mechanics, and mathematical models are being used to provide a better understanding of grain pressure phenomena, to develop more logical approaches and methods for calculating such pressures, and to formulate specific recommendations for much broader studies of actual pressures and loads occurring in full-scale storage facilities.

A comprehensive literature survey containing more than 100 entries has been completed. The survey includes material published between the years 1883 and 1966, on a worldwide basis. Some 20 factors affecting grain pressures in storage structures have been classified into four main categories as follows: Grain characteristics, bin characteristics, state of the system, and environmental effects.

The investigation and development of mathematical models of pressure mechanisms of the grain storage system are underway. Included are analytic, algebraic, numerical, and topological models. Analytic models are being investigated in terms of ordinary differential and partial differential equations. Initial results with algebraic models show that the model satisfactorily predicts lateral grain pressures for normal values of parameters. Topological model work is underway on the theory of grain-pile transformations. A complete library (51 programs consisting of more than 6,000 IBM cards) has been acquired, edited, compiled and made compatible with an available computer system. This combined system makes it feasible to obtain unique results related to the mechanism of grain-pile transformations. Although the programming and direct use of computers is greater than was anticipated, the progress of the investigations is being facilitated.

E. Uniform Blending of Seed

At State College, Miss., under a research cooperative agreement with Mississippi Agricultural Experiment Station, the study was continued on uniformly blending seed lots. Clear plastic bins 4 ft. by 4 ft. by 8 ft. high, were constructed to individually test 5 different static blending devices. In the bin unloading operation, the device causes material to flow from various portions of the bin, thus causing blending of the material at the point of discharge. Initial tests were conducted using vari-colored plastic pallets to study the blending action. Analysis of samples is aided by the use of an electronic color sorter. Results of the initial test show adequate mixing is obtained only during the time required to unload one-half the bins. Further tests are now in progress.

F. Grain Transport in Boxcars. An analysis was made of grain losses and car defects in 1,989 boxcars of wheat, corn, and soybeans inspected at unloading points in Kansas City, Minneapolis, and Chicago. The objective was to measure the amount of grain loss from various causes during transport.

Information was obtained on the condition of the grain doors, presence of holes in the car floor, presence of grain trapped behind defective car walls, presence of grain leads, condition of the interior of the car, amounts of grain left in cars after unloading, and grain samples removed from cars. Grain taken for samples averaged 7 pounds a car. Grain left in the cars after unloading in 94 percent of the cars was 28 pounds per car. In 8.6 percent of the wheat cars, losses of 804 pounds per car resulted from holes in the car floor and defective walls, while data for those losses in corn and soybean cars were inconclusive.

There appears to be need for two other improvements. One is a new type of grain door which would require fewer nails for installation, thereby causing less damage to door posts and adjacent areas in the car. Another is more accurate weighing practices at origin to help industry to obtain a clearer picture of losses.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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Handling, Drying and Storing Rice

- Louvier, F. J. and Calderwood, D. L. 1967. Breakage of Milled Rice at Different Free Fall Heights. Paper presented at annual meeting of the Southwest Region of the American Society of Agricultural Engineers, Stillwater, Okla.
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COOPERATIVE MARKETING
Marketing Division, FCS

Problem: Farmers continue to expand their use of cooperatives in marketing the products of their farms. In light of the rapid and complex changes taking place in technology and in market organization and practices, research is needed to help farmer cooperatives and other marketing agencies perform needed marketing services both more efficiently and more effectively. Farmer-directors, managers and others, including the public, need more information to assist in making decisions on how cooperatives can maintain and strengthen the bargaining power of farmers, increase efficiency and reduce costs of marketing, and better meet the needs of our mass distribution system for large quantities of products on a specification basis.

Farmer cooperatives are an important part of the distribution system and represent a major potential for meeting farmers' marketing problems in our modern, dynamic system. They are organized and operated to increase farmers' net income. However, cooperatives face many problems in achieving this goal. Cooperatives must find ways to consolidate volume, for example, through internal growth, merger, acquisition or federation, to strengthen their market position and meet the needs of mass merchandising. Ways must be found to reduce costs by increasing efficiency through improved operating methods, better organization and management, and more use of new technologies.

USDA AND COOPERATIVE PROGRAM

The Department conducts a continuing long-range program of research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operation, and role of farmer cooperatives in marketing. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms. The work is centered in Washington, D.C. Many of the studies, however, are done in cooperation with various State experiment stations, extension services, and departments of agriculture.

The number of Federal scientist man-years devoted to this research totals 3.9 of which 3.2 man-years relate to work on grain, and 0.7 on forage crops.

PROGRAM OF STATE EXPERIMENT STATIONS

Most commodity marketing research of the agricultural experiment stations is helpful to marketing cooperatives. Some projects, however, deal specifically with cooperative marketing problems, opportunities, and impacts. The total research effort on cooperative marketing in the State experiment stations is 2.8 scientist man-years.

Many State experiment stations do a considerable amount of research on technical aspects of feeds, fertilizers, seed, farm equipment, and farm supplies that is of value to purchasing cooperatives. A limited number of projects also deal specifically with cooperative purchasing problems, opportunities, and impacts.

The total research effort on cooperative purchasing in the State experiment stations is 3.8 scientist man-years.

A large part of the research in this area is devoted to the financing problems of cooperatives. This involves study of the financial structure and financing methods of cooperatives to determine those that are the most satisfactory from the standpoint of providing adequate capital for growth and treating patrons equitably.

Other research deals with cooperative information sources in performing management functions of planning and controlling, membership control of cooperatives, and socio-economic relationships existing between low-income farmers and the cooperatives to which they belong.

A total of 5.3 scientist man-years is being devoted to research in this area.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Improving the Organization, Financing, and Management of Marketing Cooperatives

Grain.--Work is continuing with eight regional grain cooperatives building a large export elevator in the New Orleans area. The Service completed another study on the economic feasibility of constructing and operating a cooperative on the Mississippi River.

The annual analysis of the operations and financial status of regional grain cooperatives showed they were handling more grain with greater emphasis on exports, merchandising, and processing. A study of inventory controls, practices, and responsibilities at local cooperative elevators was completed.

Work is being carried on with Agricultural Experiment Stations in the South and with the Tennessee Valley Authority on grain marketing, processing, utilization, and transportation problems peculiar to that area.

B. Improving sales and distribution methods

Purchasing cooperatives are interested in increasing volume to improve buying power and keep per-unit handling costs low. Most are faced with the problem of improving efficiency in distributing supplies and providing services to meet the needs of farmers with different size operations. And many are interested in serving other rural residents in order to help build stronger rural communities.

Feed.--A report on a study of 16 poultry feed bargaining groups in California was issued. Principal findings were reported last year.

A study is underway on practices of cooperatives in the East and Midwest in pricing feed at wholesale and retail levels. Special attention is being given to various types of discounts, price adjustments, and other forms of differential pricing.

Findings thus far indicate a wide variation among 16 regional associations in the types and amounts of wholesale discounts granted. Seven grant quantity discounts on large individual feed transactions, and four grant their retail outlets a volume discount on annual feed purchases above a specified minimum. Eight provide price adjustments upon proof that a price adjustment is necessary to meet competition. Nine regionals deliver feed direct from the regional's mill to large volume feed patrons at the wholesale price.

The 79 retail cooperatives or branches studied also show wide variations in types and amounts of discounts granted. Variations in discount rates and quantity purchases to obtain the discount for different kinds of feed appear to be dictated in large measure by what is necessary to meet competition.

Of the 79 local outlets, 67 allow a quantity discount on large individual feed transactions, 2 have no definite policy, and 9 do not grant quantity discounts of any type. Twenty nine locals grant volume discounts on large annual feed purchases. Thirty-five locals receive a discount for cash or payment within a specified number of days.

C. Potentials of Cooperatives in Farm Production Supplies and Farm Services

Cooperatives are interested in diversifying services, integrating operations, and expanding both in areas now served and in new areas. Research will help directors and managers plan and implement programs and services for farmers and other rural residents.

Feed (dehydrated alfalfa).--Work in this area was initiated to: Determine conditions necessary for establishing successful alfalfa dehydrating plants; evaluate the experience of cooperatives and non-cooperative alfalfa dehydrating operations; and develop guidelines for successful dehydrating operations by cooperatives.

A study is underway of 35 alfalfa dehydrating plants (including both cooperative and proprietary) operating in Nebraska, Kansas, Colorado, California, Texas, Arkansas, Ohio, and Minnesota. In addition, records of a number of out-of-business cooperative dehydrating plants are being studied to determine causes of failure.

Preliminary findings indicate: Dehydrating operations can be successful if located well and prudently managed; cooperative dehydrating experience has been neither worse nor better than that of proprietary operations; and cooperative success in alfalfa dehydrating depends largely on ability and willingness of cooperative members to supply an adequate volume of alfalfa or on how well dehydrating fits in with other activities of the cooperative, or on both.

Montana State University is performing this work under contract.

D. Transportation and Physical Distribution by Farmer Cooperatives

Grain transportation and handling by farmer cooperatives.--Principal findings of a study of ownership and leasing of covered hopper cars by cooperatives indicate:

Cooperatives operate their own hopper cars to provide faster delivery service and thus help build sales.

Ownership of hopper cars may offer opportunities for savings that will allow a hopper car to be operated fewer miles per month than a leased car and still break even.

PUBLICATIONS USDA AND COOPERATIVE PROGRAMS

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ECONOMICS OF MARKETING
Marketing Economics Division, ERS

Problem: Economic research in agricultural marketing provides a framework for developing and maintaining an effective and efficient system of marketing farm products and assuring equitable returns to farmers and marketing agencies. The marketing of farm products continues to become more complex and dynamic because of advances in technology, changes in composition and location of the population, and demands for meeting food and fiber needs in a large part of the world. Not only are structural changes taking place within the marketing segment of the economy but large segments of the processing industry are relocating to meet shifts occurring in labor resources, transportation rates and services, and consumer markets. Producers and distributors must be armed with the most up-to-date and accurate information available to cope with and adjust to changes occurring within and outside the agricultural economy.

Within the framework of the competitive system the food and fiber industries must perform in an efficient manner to maintain viable industries and help sustain a high standard of living. Marketing economics research provides a service in collecting, analyzing and publishing objective information. The information furnished through research is a form of market intelligence which the private enterprise system utilizes in making sound decisions in the marketing of farm products. Likewise, research findings provide a basis for developing guidelines in public policy as well as concepts for needed new legislation.

Marketing research helps facilitate the communication of consumer wants and desires back through the marketing system to the producer. As never before, information is needed to guide and direct the production and development of new products to meet the demands of a rapidly changing population. Producers, processors, and distributors must constantly seek an understanding of the economics of product quality, variety, and substitution to be responsive to consumer demands and utilize resources efficiently.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing long-term program of economic research designed to provide timely and accurate market intelligence to producers, processors and distributors. The program of work involves both basic and applied aspects of marketing economics research. The program covers commodity and functional problems that are regional or national in scope. In addition to the long-term, on-going research work of the Division, frequently short-term, service-type assignments are carried out for the Secretary of Agriculture or other agencies within the Department having specific problems for which the staff of the Division is uniquely equipped to analyze and make recommendations.

Research studies are often conducted in cooperation with other USDA agencies, other Federal departments, and State agricultural experiment stations. On occasion, cooperative work is undertaken with processors and distributors of agricultural products, transportation agencies, and agriculturally oriented groups. Financial contributions to the Division's research efforts are sometimes made by industry groups which provide a strengthening of the research effort.

The research program and related program activities are conducted from headquarters in Washington, D.C. A limited number of field stations are located throughout the United States, a major part of them being at land-grant institutions. Field station personnel perform a special service by keeping the Division alerted and informed on emerging problems in marketing as well as conducting joint research projects with station personnel. Also, economists are located at each of the four USDA Utilization Research and Development Laboratories.

A total of 118 scientist man-years are devoted to this area of marketing research of which 10.1 scientist man-years are devoted to problems of the grain and feed industries. The manpower is divided as follows: 3.0 scientist man-years to resource allocation; 1.0 scientist man-years to studies of the competitive situation; 0.2 to the role of consumers in marketing and 5.9 to location and growth economics.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Efficiency of Resource Allocation in Marketing

Rice

A survey of distribution patterns for the domestic marketing of American rice is being initiated. The rice industry has requested an updating of earlier studies of the rice industry structure, practices, and marketing channels. This research will assist the industry in its efforts to expand the market for rice.

Mixed Feed

A comprehensive economic-engineering analysis of feed mill operations has been completed. Total costs for manufacturing mixed feeds ranged from \$7.13 per ton for the 80-ton operation to \$3.04 per ton for the 300-ton operation per 8-hour day. Lowest costs were found in plants which did not pellet or package feed. Operating cost for manufacturing mixed feeds was estimated to be about 20 percent less for plants which operated 16 hours per day than for plants which operated only 8 hours per day.

Bakery Operations

A study of bakery plants which had installed the continuous mix process between 1956 and 1961 showed that the plants installing the continuous mix process increased their total crude value added by 27 percent as compared to an average of 2.8 percent for the total industry. The number of production workers increased by 4 percent in such equipped plants. This compared with average decrease of 0.8 percent for the baking industry as a whole. The difference in numbers of workers and plants in the industry is explained by multi-establishment companies which eliminated their most inefficient establishments, and supplied their needs from their newly equipped continuous mix plants, and by elimination of single establishment firms too small to install the new process.

Comparisons of states with and states without continuous mix establishments (1956-64) showed that in states with continuous mix plants there was an 18 1/2 percent drop in establishment numbers, and a 13.4 percent drop in the total number of employees. In states without such plants the number of establishments dropped 2.7 percent and the total number of employees by 6.2 percent. In states with continuous mix plants the impact reported by counties with and without such plants was about the same. This result is consistent with each plant's capability of shipping from plants in continuous mix counties to markets in counties which do not have continuous mix plants.

B. Competitive Situation of Input and Output Marketing Firms

Bakery Products

A revised approach for developing information on price spreads for marketing white bread has been completed and a report prepared for publication. An upward trend has prevailed since 1947-49 in farm-retail price spreads for a 1-pound loaf of bread marketed through retail stores. The rate of increase in bread prices has more than doubled the rate for all foods purchased for home consumption. The increases in prices correspond closely with the increases in marketing spreads. The farm value of ingredients used in making bread has declined and only recently has exceeded the 1947-49 level. The increased marketing spread for bread has largely been a reflection of higher operating costs--particularly in the selling and distribution functions. In 1966, consumers paid an average price of 22.2 cents for a 1-pound loaf of bread. The increase was 1.3 cents a loaf alone in 1965. This increase was exceeded in 1951 when the price increase was 1.4 cents per loaf over 1950. Contrary to the long-term trend, retail prices for bread in the first two quarters of 1967 averaged slightly lower than for the fourth quarter of 1966.

C. Role of Consumers in Marketing

Bakery Products

An evaluation of the market potential for frozen dough in the United States showed that major industry growth occurred between 1962 and 1965. An important factor in this growth was the lower retail price for frozen dough. The future growth of the frozen dough industry will be influenced by the solution of technical problems such as improvement in yeast characteristics, increased shelf life, and reduction in preparation time.

A study to assess wheat quality factors and their effect on milling and baking qualities is being initiated in cooperation with Kansas State University. This research will evaluate current criteria for grades and also will develop and evaluate new criteria of milling and baking qualities of wheat. Tests will be made for establishing the relationship between quality factors in wheat and milling and baking qualities. These tests will aid in developing factors useful in forecasting the baking qualities of different varieties of wheat.

Feed

In the past year, an important accomplishment has been the completion of a long-range research project in the feed area. Purpose of this research was to evaluate the economics of the new feed ingredients developed by utilization researchers. The evaluation was based on an adaptation of a least-cost linear programming matrix which allowed a determination of the quantity of new feed materials that will meet the formula requirements for different animal rations at least cost, and the price range in which these feed materials must fall to make them competitive with other feeds supplying the same nutrients. Initial attention was given to alfalfa meals of differing protein contents. Eventually, consideration will be given to safflower, castorbean meal, and to mill feeds. Of importance to program guidance in this area is the development of this type of matrix for analysis, coupled with the fact that computers are now available at most of the laboratories and staff members will be able to make computer runs for other new feed ingredients to determine their intrinsic values in different animal rations.

An important phase of the utilization research program is the development of new and improved industrial uses of agricultural commodities. Major economic research efforts to provide guidance to the utilization research program on industrial uses was confined in the past reporting year to the use of starch in textile manufacturing, the impact of non-woven manufacturing on textile use, and future prospects for flaxseed.

The study of cereal starch use in textile processing indicates that its main competitive strength is in warp yarn sizing in woven goods manufacture where about 80 percent (or 350 million pounds) of all starch in textiles is used. Population growth and increasing per capita incomes have a positive (indirect) affect on the demand for starch in textiles. Also exerting positive influence are the trends toward (1) spun-fiber relative to filament yarn in total synthetics and (2) synthetic-natural fiber blends in total wovens. Negative influences include competition from nontextile materials and the replacement of woven textiles by knits, bonded fiber fabrics and others. The loss of the starch warp yarn sizing market from textile trends amounted to about 12.3 percent **over** a decade with two-thirds of the loss caused by encroachment of nontextiles and one-third caused by other constructions replacing wovens.

D. Location and Growth Economics

Grain

A study of the influence of changes in transportation rates on the Midwest grain industry structure and practices is underway in cooperation with Oklahoma State University.

A study has been initiated at the request of the U.S. Army Corps of Engineers to evaluate the economic impact of extending the Missouri River waterway on the grain industry of the upper Missouri River Valley. This research will aid the Corps of Engineers in their decision concerning the feasibility of extending the Missouri River waterway from Sioux City, Iowa, to Yankton, South Dakota. It also will assist the grain industry of the upper Missouri River Valley in evaluating alternative locations for handling, storing and processing facilities, and market outlets if this extension were made.

Mixed Feed

A study of the cost and location of mixed feed plants in the Midwest is underway in cooperation with Purdue University. It will provide information and evaluations of various plant locations and distribution alternatives. Such information and analyses can be useful to firm investment decision-makers who are analyzing the feasibility of building a new plant or remodeling an existing one. If the decision is to build a new plant, these analyses would assist in evaluating alternative locations.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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CONSUMER PREFERENCE AND QUALITY DISCRIMINATION --
HOUSEHOLD AND INDUSTRIAL
Standards and Research Division, SRS

Problem. Domestic consumption of agricultural commodities depends on the behavior of some 190 million consumers. But, in our complex marketing economy, it has become almost impossible for consumers to discuss their preferences, opinions, and dissatisfactions with producers and marketers. Knowledge of consumer reactions to agricultural products is becoming increasingly important because we are in a period of rapid change. There is a growing challenge to farm products and farm income from a wide variety of competitive products of nonagricultural origin; there is a proliferation of mixtures, forms, processes and other innovations affecting farm products; and there is increasing awareness that mistakes in developing, producing, and marketing farm products are costly not only to the farmer but to processors and handlers as well. An understanding of consumer reactions and the reasons behind them is essential to planning improvements in the production, marketing, and processing of agricultural products, developing educational programs, setting or revising grades or standards, evaluating new products developed by the Department's utilization laboratories, and identifying areas on which technical research should be focused to provide farm products in the forms and with the characteristics that will increase consumer acceptance and more closely satisfy consumer demand.

USDA AND COOPERATIVE PROGRAM

The Special Surveys Branch provides the consumer, in a scientific and unbiased manner, with an opportunity to say what he or she thinks about agricultural products by conducting applied research among representative samples of household, industrial, or institutional consumers and potential consumers. Such research may determine preferences, opinions, buying practices, and use habits with respect to various agricultural commodities; the role of competitive products; acceptance of new or improved agricultural products, consumers' ability to discriminate among products with varying attributes, and the preferences associated with specific forms. These studies of the opinions, preferences, knowledge and habits of consumers which affect their purchase and use of farm products provide a line of communication from consumers back to those concerned with production and marketing, and are complementary to the marketing and economic research of the Economic Research Service and the Consumer and Marketing Service as well as to utilization research of the Agricultural Research Service.

In addition to conducting studies of consumer preference and discrimination, the Branch also provides consultants and conducts special studies, upon request, for other agencies in the USDA or within the Federal Government,

when survey methods can be usefully applied to the evaluation of programs, services, or regulatory procedures of interest to the requesting agencies.

The research is carried out in cooperation with other USDA or Federal agencies, State departments of agriculture, experiment stations, land-grant colleges, and agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are sometimes conducted by the Washington staff with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology or other social sciences, in Washington, D.C., which is headquarters for all the research whether it is conducted under contract or directly by the Branch. The Federal scientific effort devoted to research on consumer preference for cereal products during the past year totaled 0.8 scientist man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Consumer Preference

Potatoes, Rice and Wheat. The coding and tabulating of data from a nationwide study collecting information from homemakers on their use of and opinions about selected potato, rice, and wheat products have been completed, and a final report is being prepared for publication in 1968.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None

IMPROVEMENT OF CROP ESTIMATING PROCEDURES
Standards and Research Division, SRS

Problem. The Statistical Reporting Service prepares a large number of official estimates for agricultural and related enterprises. These statistics are published in the more than 700 reports issued each year. The critical need for precision estimates for the agricultural economy makes it imperative that modern statistical theory and methods be developed and incorporated into the collection and analyses of agricultural statistics. Many new techniques have been developed and introduced into the estimating procedures. However, owing to the changing structure of agriculture, the development of new technologies and the demand for more and better statistics there is an urgent need for continued research and study to devise more efficient sample survey methods to insure continued improvement in the quality of SRS statistics.

USDA AND COOPERATIVE PROGRAM

The Statistical Reporting Service conducts a program of applied research designed to strengthen and improve the methodology used in collecting agricultural statistics. The principal disciplines involved are mathematics, statistics and probability but other disciplines relating to a particular subject or field are employed as required. Examples of these subjects are plant physiology, psychology, cartography and photogrammetry. The current program consists of 6.0 scientist man-years per year devoted to the study of sampling techniques and survey methods, and 4.0 scientist man-years working on methods for forecasting and estimating the yields of important crops. Work under this program is done in Washington, D.C., and in SRS field offices located in the States concerned.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Wheat

To discover additional factors that may be useful in the forecasting models, especially for early season forecasts, intensive observations were made in eight winter wheat fields, four each in Oklahoma and in Oregon, during the 1966 spring growing season. Two sample plots, each divided into three subplots, were located in each field. One subplot was used for making weekly observations, and another was used as a check plot to determine the effect of the weekly observations on the plants subjected to that regime. The third subplot was used for clipping stalks for laboratory analysis. Information was also obtained for several environmental factors including variety, fertilizer applications, rate of seeding, amount and time of irrigation, soil moisture, soil type, and soil fertility.

Analysis of the data show that: 1. The productivity of plots subjected to weekly handling is not significantly different from the check plots.
2. A more efficient estimate of the average weight per head could be obtained by taking a 5 head sample from each of 2 sample units in each field rather than by following the current procedure of a single 10 head sample from only one of the two units.

Additional work will be conducted during the 1967 growing season, particularly with respect to possible correlation between the size of the flag leaf and weight of grain per head and with methods of measuring soil moisture.

B. Hay Forage

A study of hay forage yield forecasting techniques was made on ten selected farms in two counties in Iowa. Observations were made in one field of alfalfa or alfalfa mixture for hay on each farm. Three pre-harvest visits were made to each field. These were timed respectively, at four weeks before, two weeks before, and immediately before the expected harvest date. On each pre-harvest visit, forage harvested from 10 randomly located plots, each 30" by 20', was weighed, dried, and reweighed. Actual production less harvesting loss was obtained for each field by counting the total number of bales and weighing a sample of the bales.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None

ECONOMIC AND STATISTICAL ANALYSIS
Economics and Statistical Analysis Division, ERS

Problem. Frequent accurate appraisals of the economic prospects for important agricultural commodities are necessary if farmers are to plan and carry out their production and marketing activities in an efficient and profitable way. The typical farmer cannot afford to collect and analyze all the statistical and economic information necessary for making sound production and marketing decisions. Such information is provided through a flow of current outlook information; the development of longer range projections of the economic prospects for the principal agricultural commodities; and analyses of the economic implications of existing and proposed programs affecting major farm commodities.

Producers, processors, distributors, and consumers need information based on accurate quantitative knowledge of the interrelationships among prices, production and consumption of farm products, and other factors. Similarly, Congress and the administrators of farm programs need such economic information to evaluate existing and alternative programs or policies in terms of their probable impact on production, consumption, and prices at both the farm and retail levels. The research program in this area provides the information for strengthening outlook and situation work, and for appraising alternative policies for agricultural products.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of basic research concerning the factors affecting prices, supply, and consumption of principal agricultural commodities and the analyses of the situation and outlook for selected commodities. The Federal scientist man-years involved for food grains are 2.0 and for feed grains 2.5 annually, of which 1.0 are devoted to work on the supply and demand for grains and 3.5 to work on the grain situation and outlook analysis. The program is carried on in Washington, D.C.

PROGRAM OF STATE EXPERIMENT STATIONS

For the most part the States depend heavily on the USDA for across-the-board commodity situation and outlook research. However, the State extension staff members supplement and adapt such research information to meet the commodity situation of their States. The total direct research effort at State experiment stations in the situation and outlook area is approximately 10.0 scientist man-years. While not designed as outlook research, much of the research conducted by the experiment stations contributes to improved

understanding of price-making forces, which in turn improves market situation analysis and price forecasting.

Many of the States carry on supply, demand, and price analyses for the products of their State. Much of the research is commodity oriented, though some projects are of a highly mathematical and theoretical nature aimed at improving price analyses methodology. A total of about 39.4 scientist man-years is devoted directly to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Situation and Outlook Analysis

1. Food Grains

For 1966-67 attention was increasingly focused on wheat by individual market class. Hard red winter wheat, the mainstay of the Food for Freedom Program, was in particularly short supply relative to past levels. Analyses were made of the possibility of substituting other classes of wheat and coarse grains. Stocks and disappearance of wheat were estimated by class, by quarters, and by States. Larger commercial export demand drew heavily on some other classes of wheat that were potentially in short supply.

With the coming of the large 1967 crop and prospects for increasing the carryover, emphasis was placed on (1) means of maintaining and stabilizing prices during harvest, (2) the most effective utilization of a crop which was more largely composed of soft wheats than at any time in recent years, and (3) means of removing the Government from the market to permit increased use of the price system to allocate supplies.

The situation reports carried (1) new and additional material for individual classes of wheat with emphasis on graphic material for presentation to regional groups, (2) explanation of the actual returns to producers including non-market payments, (3) revised statistical material resulting from the 1964 Census of Agriculture and the 1963 Census of Manufactures, and (4) expanded statistics and discussion on milled rice supply and disappearance.

2. Feed

Changes in the feed grain situation in recent years have made it necessary to give increasing attention to the factors affecting feed grain requirements, both domestic and export, and a desirable level of feed grain carryover. The Feed Grain Program, and increased demand for feed, resulted in a reduction in the carryover from a record 85 million tons of feed grains in 1961 to about 37 million tons in 1967. The program was changed in 1967 to enable participating farmers to expand acreage and production. Alternative programs are under study for 1968. In 1966/67, prices of feed grains averaged 3 percent above a year earlier and 22 percent above the post-war low of 1960/61.

B. Demand, Supply and Price Analysis

1. Food Grains

With the changed wheat situation last year, whereby prices moved well above the loan, additional attention was given to the relationship of futures markets to cash markets. This required more intensive analysis of privately held stocks and changes in holdings by various segments of the private marketing sector of the wheat economy.

Work performed for the Secretary's Office and the Congress included an analysis of the wheat production, marketing, and processing industries and its relation to the national economy, further analysis of the factors influencing the Chicago wheat market, and a study of export payment differentials for various types of rice and their effect on commercial exports.

2. Feed Grains and Other Feeds

With exports becoming an increasingly more important outlet for U.S. feed grains, special analysis was conducted during 1966/67 of foreign supplies and demand and their influence on U.S. exports. In the early 1950's U.S. exports made up only about 15 percent of total farm sales; exports rose to 35 percent of the sales total in the 1965/66 season. In 1966/67, exports dropped nearly a fourth from the record 29 million tons shipped in 1965/66. A major factor was the larger production in a number of foreign countries which reduced the demand for U.S. feed grains. Although shipments of feed grains to India under the P. L. 480 Program rose sharply in the last 2 years, 85 to 90 percent of feed grain exports have been commercial sales.

Because of the importance of the relationship between livestock and feed, special analyses of livestock-feed relationships were initiated. A study was made of the relationship between livestock numbers in terms of grain-consuming animal units and the total tonnage of feed grains and other concentrates fed. The number of grain-consuming animal units was estimated on a quarterly and a semi-annual basis to improve estimates of the consumption of feed during the marketing year. The results of these studies are being prepared for publication.

Special analyses were run of the important factors influencing feed grain prices. Results of these studies were used in the outlook and situation work.

Over the past 20 years there has been an upward trend in commercial sale of hay by U.S. producers, both in tonnage and as a percentage of the crop. Basic analysis was conducted on factors associated with hay prices in important producing regions. Results of this work will be published in the Feed Situation.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Food Grains

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Feed

Clough, Malcolm. Feed Situation. Published 5 times a year. ERS, USDA. Washington, D.C.

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